PROCEEDINGS

OF

THE AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE,

THIRTY-FIFTH MEETING,

HELD AT

BUFFALO, NEW YORK,

AUGUST, 1886.

SALEM:
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JANUARY, 1887.

EDITED BY

FREDERICK W. PUTNAM,

Permanent Secretary.

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The title of paper on page 275 "OSPHRADIUM IN CREPIDULA" should be attributed to HENRY LESLIE OSBORN of Lafayette, Indiana, and not to HENRY F. OSBORN of Princeton.

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[1] Committees are expected to present their reports to the STANDING COMMITTEE not later than the fourth day of the meeting. Any report sent to the PERMANENT SECRETARY, a month before the next meeting, will be put in type previous to the meeting.

7. *Committee on Anatomical Nomenclature, with Special reference to the Brain.*

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H. F. OSBORN of Garrisons,
T. B. STOWELL of Cortland,
B. G. WILDER of Ithaca,
FRANK BAKER of Washington.

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MEETING.	DATE.	PLACE.	CHAIRMAN.	SECRETARY.	ASSIS'T SEC'Y.	TREASURER.
1st	April 2, 1840,	Philadelphia,	Edward Hitchcock,*	L. C. Beck,*		
2d	April 5, 1841,	Philadelphia,	Benjamin Silliman,*	L. C. Beck,*	B. Silliman, jr.,* C. B. Trego,*	
3d	April 25, 1842,	Boston,	S. G. Morton,*	C. T. Jackson,*	J. D. Whitney, M. B. Williams,*	
4th	April 26, 1843,	Albany,	Henry D. Rogers,*	B. Silliman, jr.,*		John Locke.*
5th	May 8, 1844,	Washington,	John Locke,*	B. Silliman, jr.,* O. P. Hubbard,		Douglas Houghton.*
6th	April 30, 1845,	New Haven,	Wm. B. Rogers,*	B. Silliman, jr.,* J. Lawrence Smith,*		Douglas Houghton.*
7th	Sept. 2, 1846,	New York,	C. T. Jackson,*	B. Silliman, jr.,*		E. C. Herrick.*
8th	Sept. 20, 1847,	Boston,	Wm. B. Rogers,†*	Jeffries Wyman,*		B. Silliman, jr.*

* Deceased.

† Professor ROGERS, as chairman of this last meeting, called the first meeting of the new Association to order and presided until it was fully organized by the adoption of a constitution. As he was thus the first presiding officer of the new Association, it was directed at the Hartford meeting that his name be placed at the head of the Past Presidents of the American Association for the Advancement of Science.

MEETINGS AND OFFICERS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

MEETING.	DATE.	PLACE.	PRESIDENT.	VICE-PRESIDENT.	GENERAL SECRETARY.	PERMANENT SEC'Y.	TREASURER.
1st	Sept. 20, 1848,	Philadelphia, Pa.,	W. C. Redfield,*		Walter R. Johnson,*		Jeffries Wyman.*
2d	Aug. 14, 1849,	Cambridge, Mass.,	Joseph Henry,*		E. N. Horsford, 1		A. L. Elwyn.*
3d	Mar. 12, 1850,	Charleston, S. C.,	A. D. Bache,* 2		L. R. Gibbs, 3		St. J. Ravenel.* 4
4th	Aug. 19, 1850,	New Haven, Conn.,	A. D. Bache,*		E. C. Herrick,*		A. L. Elwyn.*
5th	May 5, 1851,	Cincinnati, Ohio,	A. D. Bache,*		W. B. Rogers, 5*	S. F. Baird,	S. F. Baird. 6
6th	Aug. 19, 1851,	Albany, N. Y.,	Louis Agassiz,*		W. B. Rogers,*	S. F. Baird,	A. L. Elwyn.*
7th	July 28, 1853,	Cleveland, Ohio,	Benjamin Pierce,*		S. St. John,* 7	S. F. Baird,	A. L. Elwyn.*
8th	April 26, 1854,	Washington, D. C.,	J. D. Dana,		J. Lawrence Smith,*	Joseph Lovering,	J. L. LeConte* 8
9th	Aug. 15, 1855,	Providence, R. I.,	John Torrey,*		Wolcott Gibbs,	Joseph Lovering,	A. L. Elwyn.*
10th	Aug. 20, 1856,	Albany, N. Y.,	James Hall,		B. A. Gould,	Joseph Lovering,	A. L. Elwyn.*
11th	Aug. 12, 1857,	Montreal, Canada,	Alexis Caswell,* 9	Alexis Caswell,*	John LeConte,	Joseph Lovering,	A. L. Elwyn.*
12th	April 28, 1858,	Baltimore, Md.,	Alexis Caswell,* 10	John E. Holbrook,*†	W. M. Gillespie,* 11	Joseph Lovering,	A. L. Elwyn.*
13th	Aug. 3, 1859,	Springfield, Mass..	Stephen Alexander,*	Edward Hitchcock,*	William Chauvenet,*	Joseph Lovering,	A. L. Elwyn.*
14th	Aug. 1, 1860,	Newport, R. I.,	Isaac Lea,*	B. A. Gould,	Joseph LeConte,	Joseph Lovering,	A. L. Elwyn.*
15th	Aug. 15, 1866,	Buffalo, N. Y.,	F. A. P. Barnard,	A. A. Gould,* 12	Elias Loomis, 13	Joseph Lovering,	A. L. Elwyn.†*
16th	Aug. 21, 1867,	Burlington, Vt.,	J. S. Newberry,	Wolcott Gibbs,	C. S. Lyman,	Joseph Lovering,	A. L. Elwyn.†*
17th	Aug. 5, 1868,	Chicago, Ill.,	B. A. Gould,	Charles Whittlesey,*	Simon Newcomb, 14	Joseph Lovering,	A. L. Elwyn.†*
18th	Aug. 18, 1869,	Salem, Mass.,	J. W. Foster,*	O. N. Rood,	O. C. Marsh,	F. W. Putnam, 15	A. L. Elwyn.†*
19th	Aug. 17, 1870,	Troy, N. Y.,	T. S. Hunt, 16	T. S. Hunt,	F. W. Putnam, 17	Joseph Lovering,	A. L. Elwyn.†*
20th	Aug. 16, 1871,	Indianapolis, Ind..	Asa Gray,	G. F. Barker,	F. W. Putnam,	Joseph Lovering,	W. S. Vaux.*
21st	Aug. 15, 1872,	Dubuque, Iowa,	J. Lawrence Smith,*	Alex. Winchell,	E. S. Morse,	Joseph Lovering,	W. S. Vaux.*
22d	Aug. 20, 1873,	Portland, Me.,	Joseph Lovering,	A. H. Worthen,†	C. A. White,	F. W. Putnam,	W. S. Vaux.*
23d	Aug. 12, 1874,	Hartford, Conn.,	J. L. LeConte,*	C. S. Lyman,	A. C. Hamlin,	F. W. Putnam,	W. S. Vaux.†*

1. In place of Jeffries Wyman, *not present.*
2. In place of Joseph Henry, *not present.*
3. In place of E. C. Herrick, *not present.*
4. In place of A. L. Elwyn, *not present.*
5. In place of E. C. Herrick, *not present.*
6. In place of A. L. Elwyn, *not present.*
7. In place of J. D. Dana, *not present.*
8. In place of A. L. Elwyn, *not present.*
9. In place of J. W. Bailey, *deceased.*
10. In place of Jeffries Wyman, *not present.*
11. In place of Wm. Chauvenet, *not present.*
12. In place of R. W. Gibbes, *not present.*
13. In place of W. P. Trowbridge, *not present.*
14. In place of A. P. Rockwell, *called home 1st day.*
15. In place of Joseph Lovering, *in Europe.*
16. In place of Wm. Chauvenet, *too ill to be present.*
17. In place of C. F. Hartt, *in Brazil.*

* Deceased. † Not present at the meeting.

MEETINGS AND OFFICERS OF THE ASSOCIATION (*Continued*).

MEETING.	DATE.	PLACE.	PRESIDENT.	VICE PRESIDENT, SECTION A.	VICE PRESIDENT, SECTION B.	CHAIRMAN OF PERMANENT SUBSECTION OF CHEMISTRY.	CHAIRMAN OF PERMANENT SUBSECTION OF ANTHROPOLOGY.	CHAIRMAN OF PERMANENT SUBSECTION OF MICROSCOPY.	CHAIRMAN OF PERMANENT SUBSECTION OF ENTOMOLOGY.
24th	Aug. 11, 1875.	Detroit, Mich.,	J. E. Hilgard,	H. A. Newton,	J. W. Dawson,	S. W. Johnson,	L. H. Morgan,*	———	———
25th	Aug. 23, 1876.	Buffalo, N. Y.,	W. B. Rogers,*	C. A. Young,	E. S. Morse,	G. F. Barker,	L. H. Morgan,*	R. H. Ward,	———
26th	Aug. 29, 1877.	Nashville, Tenn.,	S. Newcomb,	R. H. Thurston,[1]	O. C. Marsh,	N. T. Lupton,	Daniel Wilson,†	R. H. Ward,	———
27th	Aug. 21, 1878.	St. Louis, Mo.,	O. C. Marsh,	R. H. Thurston,	Aug. R. Grote,	F. W. Clarke,	———[2]	R. H. Ward,[3]	———
28th	Aug. 27, 1879.	Saratoga, N. Y.,	G. F. Barker,	S. P. Langley,	J. W. Powell,	F. W. Clarke,[4]	Daniel Wilson,	E. W. Morley,	———
29th	Aug. 25, 1880.	Boston, Mass.,	L. H. Morgan,*	Asaph Hall,	Alex. Agassiz,	J. M. Ordway,	J. W. Powell,	S. A. Lattimore,	———
30th	Aug. 17, 1881.	Cincinnati, Ohio,	G. J. Brush,	Wm. Harkness,[7]	E. T. Cox,[8]	G. C. Caldwell,[9]	G. Mallery,	A. B. Hervey,	J. G. Morris.

PERMANENT SECRETARY.	GENERAL SECRETARY.	SECRETARY OF SECTION A.	SECRETARY OF SECTION B.	SECRETARY OF PERMANENT SUBSECTION OF CHEMISTRY.	SECRETARY OF PERMANENT SUBSECTION OF ANTHROPOLOGY.	SECRETARY OF PERMANENT SUBSECTION OF MICROSCOPY.	SECRETARY OF PERMANENT SUBSECTION OF ENTOMOLOGY.	TREASURER.
F. W. Putnam,	S. H. Scudder,	{ S. P. Langley, T. C. Mendenhall,	E. S. Morse,	F. W. Clarke,	F. W. Putnam,	———	———	W. S. Vaux.*
F. W. Putnam,	T. C. Mendenhall,	A. W. Wright,	Albert H. Tuttle,	H. C. Bolton,	O. T. Mason,	E. W. Morley,	———	W. S. Vaux.*
F. W. Putnam,	Aug. R. Grote,	H. C. Bolton,	Wm. H. Dall,	P. Schweitzer,	———[2]	T. O. Summers, jr.,	———	W. S. Vaux.†*
F. W. Putnam,	H. C. Bolton,	F. E. Nipher,	George Little,	A. P. S. Stuart,	———[2]	G. J. Engelmann,	———	W. S. Vaux.†*
F. W. Putnam,	H. C. Bolton,[5]	J. K. Rees,	W. H. Dall,[6]	W. R. Nichols,*	J. G. Henderson,	A. B. Hervey,	———	W. S. Vaux.†*
F. W. Putnam,	J. K. Rees,	H. B. Mason,	C. V. Riley,	C. E. Munroe,	J. G. Henderson,	A. B. Hervey,	———	W. S. Vaux.*
F. W. Putnam,	C. V. Riley,	E. T. Tappan,[10]	Wm. Saunders,	A. Springer,[12]	J. G. Henderson,	W. H. Seaman,[11]	B. P. Mann,	W. S. Vaux.†*

1 In the absence of E. C. Pickering.
2 The Subsection united with Sec. B.
3 In the absence of G. S. Blackie.
4 In the absence of Ira Remsen.
5 In the absence of George Little.
6 In the absence of A. C. Wetherby.
7 In the absence of A. M. Mayer.
8 In the absence of George Engelmann.
9 In the absence of W. R. Nichols.
10 In the absence of John Trowbridge.
11 In the absence of S. P. Sharples.
12 In place of H. W. Wiley, called away.
* Deceased.
† Not present.

MEETING.	DATE.	PLACE.	PRESIDENT.	VICE PRESIDENTS.				
				Section A.	Section B.	Section C.	Section D.	Section E.
31st	Aug. 23, 1882.	Montreal, Can.	J. W. Dawson,	W. A. Rogers,[1]	T.C. Mendenhall,	H. C. Bolton,	W. P. Trowbridge,	E. T. Cox,
32nd	Aug. 15, 1883.	Minneapolis, M.	C. A. Young,	W. A. Rogers,	H. A. Rowland,	E. W. Morley,	De Volsen Wood,[7]	C.H. Hitchcock,
33rd	Sept. 3, 1884.	Philadelphia, Pa.	J. P. Lesley,	H. T. Eddy,	J. Trowbridge,	J. W. Langley,	R. H. Thurston,	N. H. Winchell,
34th	Aug. 26, 1885.	Ann Arbor, Mich.	H. A. Newton,	W. Harkness,[15]	S. P. Langley,[16]	N. T. Lupton,[17]	J. Burkitt Webb,	Edward Orton,
35th	Aug 18, 1886.	Buffalo, N. Y.	E. S. Morse,	J. W. Gibbs,	C. F. Brackett,	H. W. Wiley,	O. Chanute,	T. C. Chamberlin,

VICE PRESIDENTS.				Permanent Secretary.	General Secretary.	Assistant Gen. Secretary.	SECRETARIES OF SECTIONS.	
Section F.	Section G.	Section H.	Section I.				Section A.	Section B.
W. H. Dall,	A. H. Tuttle,	Alex. Winchell,[2]	E. B. Elliott,	F. W. Putnam,	Wm. Saunders,	J. R. Eastman,	H. T. Eddy,	C. S. Hastings,
W. J. Beal,	J. D. Cox,	O. T. Mason,	F. B. Hough,*	F. W. Putnam,	J. R. Eastman,	Alfred Springer,	G. W. Hough,[8]	F. E. Nipher,[9]
E. D. Cope,	T. G. Wormley.	E. S. Morse,	John Eaton,	F. W. Putnam.	Alfred Springer,	C. S. Minot,[12]	G. W. Hough,	N. D. C. Hodges,
T. J. Burrill,[18]	S. H. Gage,	J. O. Dorsey,[19]	Edw. Atkinson	F. W. Putnam,	C. S. Minot,	S. G. Williams,[20]	E. W. Hyde,	B. F. Thomas,[21]
H. P. Bowditch,	——————[25]	H. Hale,	Jos. Cummings	F. W. Putnam,	S. G. Williams,	W. H. Pettee,	S. C. Chandler,	H. S. Carhart,

SECRETARIES OF THE SECTIONS.							Treasurer.
Section C.	Section D.	Section E.	Section F.	Section G.	Section H.	Section I.	
Alfred Springer,	J. B. Webb,[3]	H. S. Williams,[4]	Wm. Osler,[5]	Robt. Brown, jr.,	O. T. Mason,	F. B. Hough,[6]*	——————*
J. W. Langley,[10]	J. B. Webb,[11]	A. A. Julien,	S. A. Forbes,	Carl Seiler,	G. H. Perkins,	Jos. Cummings,	William Lilly.
H. Carmichael,[13]	J. B. Webb,	E. A. Smith,	C. E. Bessey,	R. Hitchcock,	G. H. Perkins,[14]	C. W. Smiley,	William Lilly.
F.P. Dunnington,	C. J. H. Woodbury.	G. K. Gilbert,[22]	J. A. Lintner,[23]	W. H. Walmsley.	Erm. A. Smith,*	C. W. Smiley,[24]	William Lilly.
W. McMurtrie,	William Kent,	E. W. Claypole,	J. C. Arthur,	——————[25]	A. W. Butler,	H. E. Alvord,	William Lilly.

1 In the absence of William Harkness.
2 In the absence of Daniel Wilson.
3 In the absence of C. B. Dudley.
4 In the absence of C. E. Dutton.
5 In the absence of C. S. Minot.
6 F. B. Hough was called home and J. R. Dodge acted at the close of the meeting.
7 Absent but place was not filled.
8 In the absence of W. W. Johnson.
9 In the absence of C. K. Wead.
10 W. M. McMurtrie, last three days of meeting.
11 Pro tempore.
12 In the absence of E. S. Holden.
13 In the absence of R. B Warder.
14 In the absence of W. H. Holmes.
15 In the absence of J. M. Van Vleck.
16 In place of C. F. Brackett, resigned.
17 In the absence of W. R. Nichols.
18 In the absence of B. G. Wilder.
19 In the absence of W. H. Dall.
20 In place of C. C. Abbott, not present.
21 In place of A. A. Michelson, resigned.
22 In the absence of H. C. Lewis.
23 In place of C. H. Fernald, resigned.
24 In the absence of J. W. Chickering.
25 Section permanently united to Section F.

*Deceased.

COMMONWEALTH OF MASSACHUSETTS.

IN THE YEAR ONE THOUSAND EIGHT HUNDRED AND SEVENTY-FOUR.

AN ACT

TO INCORPORATE THE "AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE."

Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows:

SECTION 1. Joseph Henry of Washington, Benjamin Pierce of Cambridge, James D. Dana of New Haven, James Hall of Albany, Alexis Caswell of Providence, Stephen Alexander of Princeton, Isaac Lea of Philadelphia, F. A. P. Barnard of New York, John S. Newberry of Cleveland, B. A. Gould of Cambridge, T. Sterry Hunt of Boston, Asa Gray of Cambridge, J. Lawrence Smith of Louisville, Joseph Lovering of Cambridge and John LeConte of Philadelphia, their associates, the officers and members of the Association, known as the "American Association for the Advancement of Science," and their successors, are hereby made a corporation by the name of the "American Association for the Advancement of Science," for the purpose of receiving, purchasing, holding and conveying real and personal property, which it now is, or hereafter may be, possessed of, with all the powers and privileges, and subject to the restrictions, duties and liabilities set forth in the general laws which now or hereafter may be in force and applicable to such corporations.

SECTION 2. Said corporation may have and hold by purchase, grant, gift or otherwise, real estate not exceeding one hundred thousand dollars in value, and personal estate of the value of two hundred and fifty thousand dollars.

SECTION 3. Any two of the corporators above named are hereby authorized to call the first meeting of the said corporation in the month of August next ensuing, by notice thereof "by mail," to each member of the said Association.

SECTION 4. This act shall take effect upon its passage.

HOUSE OF REPRESENTATIVES, March 10, 1874.
Passed to be enacted,
JOHN E. SANFORD, *Speaker.*

IN SENATE, March 17, 1874.
Passed to be enacted,
GEO. B. LORING, *President.*

March 19, 1874.
Approved,
W. B. WASHBURN.

SECRETARY'S DEPARTMENT,
Boston, April 3, 1874.
A true copy, Attest:
DAVID PULSIFER,
Deputy Secretary of the Commonwealth.

CONSTITUTION

OF THE

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Incorporated by Act of the General Court of the Commonwealth of Massachusetts.

OBJECTS.

ARTICLE 1. The objects of the Association are, by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of America, to give a stronger and more general impulse and more systematic direction to scientific research, and to procure for the labors of scientific men increased facilities and a wider usefulness.

MEMBERS, FELLOWS, PATRONS AND HONORARY FELLOWS.

ART. 2. The Association shall consist of Members, Fellows, Patrons, and Honorary Fellows.

ART. 3. Any person may become a Member of the Association upon recommendation in writing by two members or fellows, and election by the Standing Committee.

ART. 4. Fellows shall be elected by the Standing Committee from such of the members as are professionally engaged in science, or have by their labors aided in advancing science. The election of fellows shall be by ballot and a majority vote of the members of the Standing Committee at a designated meeting of the Committee.

ART. 5. Any person paying to the Association the sum of one thousand dollars shall be classed as a Patron, and shall be entitled to all the privileges of a member and to all its publications.

ART. 6. Honorary Fellows of the Association, not exceeding three for each section, may be elected; the nominations to be made by the Standing Committee and approved by ballot in the respective sections before election by ballot in General Session. Honorary Fellows shall be entitled to all the privileges of Fellows and shall be exempt from all fees and assessments, and entitled to all publications of the Association issued after the date of their election.

ART. 7. The name of any member or fellow two years in arrears for annual dues shall be erased from the list of the Association, provided that two notices of indebtedness, at an interval of at least three months, shall have been given; and no such person shall be restored until he has paid his arrearages or has been reëlected. The Standing Committee shall have power to exclude from the Association any member or fellow, on satisfactory evidence that said member or fellow is an improper person to be connected with the Association, or has in the estimation of the Committee made improper use of his membership or fellowship.

ART. 8. No member or fellow shall take part in the organization of, or hold office in, more than one section at any one meeting.

OFFICERS.

ART. 9. The Officers of the Association shall be elected by ballot in General Session from the fellows, and shall consist of a President, a Vice President from each section, a Permanent Secretary, a General Secretary, an Assistant General Secretary, a Treasurer, and a Secretary of each Section; these, with the exception of the Permanent Secretary, shall be elected at each meeting for the following one, and, with the exception of the Treasurer and the Permanent Secretary, shall not be reëligible for the next two meetings. The term of office of Permanent Secretary shall be five years.

ART. 10. The President, or, in his absence, the senior Vice President present, shall preside at all General Sessions of the Association and at all meetings of the Standing Committee. It shall also be the duty of the President to give an address at a General Session of the Association at the meeting following that over which he presided.

ART. 11. The Vice Presidents shall be the chairmen of their respective Sections, and of their Sectional Committees, and it shall be part of their duty to give an address, each before his own section, at such time as the Standing Committee shall determine. The Vice Presidents may appoint temporary chairmen to preside over the sessions of their sections, but shall not delegate their other duties. The Vice Presidents shall have seniority in order of their continuous membership in the Association.

ART. 12. The General Secretary shall be the Secretary of all General Sessions of the Association, and shall keep a record of the business of these sessions. He shall receive the records from the Secretaries of the

Sections, which, after examination, he shall transmit with his own records to the Permanent Secretary within two weeks after the adjournment of the meeting. He shall receive proposals for membership and bring them before the Standing Committee.

ART. 13. The Assistant General Secretary shall be the Secretary of the Standing Committee. He shall give to the Secretary of each Section the titles of papers assigned to it by the Standing Committee.

ART. 14. The Permanent Secretary shall be the executive officer of the Association under the direction of the Standing Committee. He shall attend to all business not specially referred to committees nor otherwise constitutionally provided for. He shall keep an account of all business that he has transacted for the Association, and make annually a general report for publication in the annual volume of Proceedings. He shall attend to the printing and distribution of the annual volume of Proceedings, and all other printing ordered by the Association. He shall issue a circular of information to members and fellows at least three months before each meeting, and shall, in connection with the Local Committee, make all necessary arrangements for the meetings of the Association. He shall provide the Secretaries of the Association with such books and stationery as may be required for their records and business, and shall provide members and fellows with such blank forms as may be required for facilitating the business of the Association. He shall collect all assessments and admission fees, and notify members and fellows of their election, and of any arrearages. He shall receive, and bring before the Standing Committee, the titles and abstracts of papers proposed to be read before the Association. He shall keep an account of all receipts and expenditures of the Association, and report the same annually at the first meeting of the Standing Committee, and shall pay over to the Treasurer such unexpended funds as the Standing Committee may direct. He shall receive and hold in trust for the Association all books, pamphlets and manuscripts belonging to the Association, and allow the use of the same under the provisions of the Constitution and the orders of the Standing Committee. He shall receive all communications addressed to the Association during the interval between meetings, and properly attend to the same. He shall at each meeting report the names of fellows and members who have died since the preceding meeting. He shall be allowed a salary which shall be determined by the Standing Committee, and may employ one or more clerks at such compensation as may be agreed upon by the Standing Committee.

ART. 15. The Treasurer shall invest the funds received by him in such securities as may be directed by the Standing Committee. He shall annually present to the Standing Committee an account of the funds in his charge. No expenditure of the principal in the hands of the Treasurer shall be made without a unanimous vote of the Standing Committee, and no expenditure of the income received by the Treasurer shall be made without a two-thirds vote of the Standing Committee.

ART. 16. The Secretaries of the Sections shall keep the records of their respective sections, and, at the close of the meeting, give the same, including the records of subsections, to the General Secretary. They shall also be the Secretaries of the Sectional Committees. The Secretaries shall have seniority in order of their continuous membership in the Association.

ART. 17. In case of a vacancy in the office of the President, one of the Vice Presidents shall be elected by the Standing Committee as the President of the meeting. Vacancies in the offices of Vice President, Permanent Secretary, General Secretary, Assistant General Secretary, and Treasurer, shall be filled by nomination of the Standing Committee and election by ballot in General Session. A vacancy in the office of Secretary of a Section shall be filled by nomination and election by ballot in the Section.

ART. 18. The Standing Committee shall consist of the past Presidents, and the Vice Presidents of the last meeting, together with the President, the Vice Presidents, the Permanent Secretary, the General Secretary, the Assistant General Secretary, the Secretaries of the Sections, and the Treasurer of the current meeting, with the addition of one fellow elected from each Section by ballot on the first day of its meeting. The members present at any regularly called meeting of the Committee, provided there are at least five, shall form a quorum for the transaction of business. The Standing Committee shall meet on the day preceding each annual meeting of the Association, and arrange the programme for the first day of the sessions. The time and place of this first meeting shall be designated by the Permanent Secretary. Unless otherwise agreed upon, regular meetings of the Committee shall be held in the committee room at 9 o'clock, A. M., on each day of the meeting of the Association. Special meetings of the Committee may be called at any time by the President. The Standing Committee shall be the board of supervision of the Association, and no business shall be transacted by the Association that has not first been referred to, or originated with, the Committee. The Committee shall receive and assign papers to the respective sections; examine and, if necessary, exclude papers; decide which papers, discussions and other

proceedings shall be published, and have the general direction of the publications of the Association; manage the financial affairs of the Association; arrange the business and programmes for general Sessions; suggest subjects for discussion, investigation or reports; elect members and fellows; and receive and act upon all invitations extended to the Association and report the same at a General Session of the Association. The Standing Committee shall receive all reports of Special Committees and decide upon them, and only such shall be read in General Session as the Standing Committee shall direct. The Standing Committee shall appoint at each meeting the following sub-committees who shall act, subject to appeal to the whole committee, until their successors are appointed at the following meeting: 1, on Papers and Reports; 2, on Members; 3, on Fellows.

ART. 19. The Nominating Committee shall consist of the Standing Committee, and one member or fellow elected by each of the Sections. It shall be the duty of this Committee to meet at the call of the President and nominate the general officers for the following meeting of the Association. It shall also be the duty of this Committee to recommend the time and place for the next meeting. The Vice President and Secretary of each Section shall be recommended to the Nominating Committee by a sub-committee consisting of the Vice President, Secretary, and three members or fellows elected by the Section.

MEETINGS.

ART. 20. The Association shall hold a public meeting annually, for one week or longer, at such time and place as may be determined by vote of the Association, and the preliminary arrangements for each meeting shall be made by the Local Committee, in conjunction with the Permanent Secretary and such other persons as the Standing Committee may designate.

ART. 21. A General Session shall be held at 10 o'clock A. M., on the first day of the meeting, and at such other times as the Standing Committee may direct.

SECTIONS AND SUBSECTIONS.

ART. 22. The Association shall be divided into Sections, namely:— A, *Mathematics and Astronomy;* B, *Physics;* C, *Chemistry including its application to agriculture and the arts;* D, *Mechanical Science and Engineering;* E, *Geology and Geography;* F, *Biology;* [G, united to section F]; A, *Anthropology;* I, *Economic Science and Statistics.* The Standing Committee shall have power to consolidate any two or more Sections temporarily, and such consolidated Sections shall be presided over by the senior Vice President and Secretary of the Sections comprising it.

ART. 23. Immediately on the organization of a Section there shall be three fellows elected by ballot after open nomination, who, with the Vice President and Secretary, shall form its Sectional Committee. The Sectional Committees shall have power to fill vacancies in their own numbers. Meetings of the Sections shall not be held at the same time with a General Session.

ART. 24. The Sectional Committee of any Section may at its pleasure form one or more temporary Subsections, and may designate the officers thereof. The Secretary of a Subsection shall, at the close of the meeting, transmit his records to the Secretary of the Section.

ART. 25. A paper shall not be read in any Section or Subsection until it has been received from the Standing Committee and placed on the programme of the day by the Sectional Committee.

SECTIONAL COMMITTEES.

ART. 26. The Sectional Committees shall arrange and direct the business of their respective Sections. They shall prepare the daily programmes and give them to the Permanent Secretary for printing at the earliest moment practicable. No titles of papers shall be entered on the daily programmes except such as have passed the Standing Committee. No change shall be made in the programme for the day in a Section without the consent of the Sectional Committee. The Sectional Committees may refuse to place the title of any paper on the programme; but every such title, with the abstract of the paper or the paper itself, must be returned to the Standing Committee with the reasons why it was refused.

ART. 27. The Sectional Committees shall examine all papers and abstracts referred to the sections, and they shall not place on the programme any paper inconsistent with the character of the Association; and to this end they have power to call for any paper, the character of which may not be sufficiently understood from the abstract submitted.

PAPERS AND COMMUNICATIONS.

ART. 28. All members and fellows must forward to the Permanent Secretary, as early as possible, and when practicable before the convening of the Association, full titles of all the papers which they propose to present during the meeting, with a statement of the time that each will occupy in delivery, and also such abstracts of their contents as will give a general idea of their nature; and no title shall be referred by the Standing Committee to the Sectional Committee until an abstract of the paper or the paper itself has been received.

ART. 29. If the author of any paper be not ready at the time assigned, the title may be dropped to the bottom of the list.

ART. 30. Whenever practicable, the proceedings and discussions at General Sessions, Sections and Subsections shall be reported by professional reporters, but such reports shall not appear in print as the official reports of the Association unless revised by the Secretaries.

PRINTED PROCEEDINGS.

ART. 31. The Permanent Secretary shall have the Proceedings of each meeting printed in an octavo volume as soon after the meeting as possible, beginning one month after adjournment. Authors must prepare their papers or abstracts ready for the press, and these must be in the hands of the Secretaries of the Sections before the final adjournment of the meeting, otherwise only the titles will appear in the printed volume. The Standing Committee shall have power to order the printing of any paper by abstract or title only. Whenever practicable, proofs shall be forwarded to authors for revision. If any additions or substantial alterations are made by the author of a paper after its submission to the Secretary, the same shall be distinctly indicated. Illustrations must be provided for by the authors of the papers, or by a special appropriation from the Standing Committee. Immediately on publication of the volume, a copy shall be forwarded to every member and fellow of the Association who shall have paid the assessment for the meeting to which it relates, and it shall also be offered for sale by the Permanent Secretary at such price as may be determined by the Standing Committee. The Standing Committee shall also designate the institutions to which copies shall be distributed.

LOCAL COMMITTEE.

ART. 32. The Local Committee shall consist of persons interested in the objects of the Association and residing at or near the place of the proposed meeting. It is expected that the Local Committee, assisted by the officers of the Association, will make all essential arrangements for the meeting, and issue a circular giving necessary particulars, at least one month before the meeting.

LIBRARY OF THE ASSOCIATION.

ART. 33. All books and pamphlets received by the Association shall be in the charge of the Permanent Secretary, who shall have a list of the same printed and shall furnish a copy to any member or fellow on application. Members and fellows who have paid their assessments in full shall be allowed to call for books and pamphlets, which shall be delivered to them at their expense, on their giving a receipt agreeing to make good any loss or damage and to return the same free of expense to the Secretary at the time specified in the receipt given. All books and pamphlets

in circulation must be returned at each meeting. Not more than five books, including volumes, parts of volumes, and pamphlets, shall be held at one time by any member or fellow. Any book may be withheld from circulation by order of the Standing Committee.

ADMISSION FEE AND ASSESSMENTS.

ART. 34. The admission fee for members shall be five dollars in addition to the annual assessment. On the election of any member as a fellow an additional fee of two dollars shall be paid.

ART. 35. The annual assessment for members and fellows shall be three dollars.

ART. 36. Any member or fellow who shall pay the sum of fifty dollars to the Association, at any one time, shall become a Life Member and as such shall be exempt from all further assessments, and shall be entitled to the Proceedings of the Association. All money thus received shall be invested as a permanent fund, the income of which shall be used only to assist in original research, unless otherwise directed by unanimous vote of the Standing Committee.

ART. 37. All admission fees and assessments must be paid to the Permanent Secretary, who shall give proper receipts for the same.

ACCOUNTS.

ART. 38. The accounts of the Permanent Secretary and of the Treasurer shall be audited annually, by Auditors appointed by the Standing Committee.

ALTERATIONS OF THE CONSTITUTION.

ART. 39. No part of this Constitution shall be amended or annulled, without the concurrence of three-fourths of the members and fellows present in General Session, after notice given at a General Session of a preceding meeting of the Association.

ORDER OF PROCEEDINGS IN ORGANIZING A MEETING.

1. The retiring President introduces the President elect, who takes the chair.
2. Formalities of welcome of the Association as may be arranged by the Local Committee.
3. Report of the list of papers entered and their reference to the Sections.
4. Other reports.
5. Announcements of arrangements by the Local Committee.
6. Election of members.
7. Election of fellows.
8. Unenumerated business.
9. Adjournment to meet in Sections.

This order, so far as applicable, to be followed in subsequent General Sessions.

MEMBERS

OF THE

AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.[1]

PATRONS.[2]

THOMPSON, MRS. ELIZABETH, Stamford, Conn. (22).
LILLY, GEN. WILLIAM, Mauch Chunk, Carbon Co., Pa. (28). **F E**
HERRMAN, MRS. ESTHER, 59 West 56th St., New York, N. Y. (29).

MEMBERS.[3]

Abbot, Griffith Evans, Ph.D., M.D., Falls of Schuylkill, Philadelphia, Pa. (33). **C H**
Abbott, James, 1509 Locust St., Philadelphia, Pa. (34).
Abert, S. Thayer, 810 19th St., N. W., Washington, D. C. (30). **A B D E I**
Adams, Chas. Francis, High School, Detroit, Mich. (34). **C B**
Agard, Dr. A. H., 1259 Alice St., Oakland, Alameda Co., Cal. (28).
Aher, Mrs. Mary R. Alling, care Rev. H. Alling, South Cairo, Greene Co., N. Y. (29). **E F C**
Alberger, Louis R., 1181 Delaware Ave., Buffalo, N. Y. (35). **C**

[1] The numbers in parentheses indicate the meeting at which the member was elected. The black letters at the end of line indicate the sections to which members elect to belong. The Constitution requires that the names of all members two or more years in arrears shall be omitted from the list, but their names will be restored on payment of arrearages. Members not in arrears are entitled to the annual volume of Proceedings bound in paper. *The payment of ten dollars at one time entitles a member to the subsequent volumes to which he may be entitled, bound in cloth, or by the payment of twenty dollars, to such volumes bound in half morocco.*

[2] Persons contributing one thousand dollars or more to the Association are classed as Patrons, and are entitled to the privileges of members and to the publications.
The names of Patrons are to remain permanently on the list.

[3] Any Member or Fellow may become a Life Member by the payment of fifty dollars. The money derived from Life Memberships is invested as a fund, the income of which is to be used only to aid in original research. Life Members are exempt from the annual assessment, and are entitled to the annual volume. The names of Life Members are printed in small capitals in the regular list of Members and Fellows.

Alexander, Miss Jane, Jamaica Plain, Mass. (33.). F
Allderdice, Wm. H., U. S. Navy, care Navy Department, Washington, D. C. (33). D
Allen, Henry C., M.D., Ann Arbor, Mich. (34). C F
Allen, J. M., Hartford, Conn. (22). D
Allen, Jno. R., Linwood, Del. Co., Pa. (33).
Allen, Dr. T. F., 10 E. 36th St., New York, N. Y. (35). F
Alvord, Benjamin, 2nd Lt. 20th Infantry, U. S. A., Fort Leavenworth, Kan. (33). A
Anderson, Newton M., 371 Sibley St., Cleveland, Ohio (30). B
Ansley, Clark F., Swedona, Mercer Co., Ill. (32). E H
Antisell, Thomas, M.D., 1311 Q St., N.W., Washington, D. C. (33). C E
Appleton, Rev. Edw. W., D.D., Ashbourne P. O., Montgomery Co., Pa. (28).
Archambault, U. E., P. O. box 1944, Montreal, Can. (31).
Arms, Walter F., Punxsutawney, Jefferson Co., Pa. (35.).
Armstrong, Lucius H., St. Nicholas, Duval Co., Fla. (30).
Armstrong, Mrs. Lucius H., St. Nicholas, Duval Co., Fla. (30).
Atkinson, Charles Heath, Brookline, Mass. (34). D I
Atkinson, Jno. B., Earlington, Hopkins Co., Ky. (26). D
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Atwood, Oscar, Rutland, Vt. (31). H
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Christie, James, Pencoyd, Pa. (33). **D**
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Stevenson, Mrs. Cornelius, 237 S. 21st St., Philadelphia, Pa. (33).
Stevenson, W. G., M.D., Poughkeepsie, N. Y. (28). F H
Stockbridge, Horace E., Amherst, Mass. (31).
Stockbridge, Levi, Amherst, Mass. (31).
Stoddard, Prof. John T., Northampton, Mass. (35). B C
Stone, Mrs. Alfred, Providence, R. I. (31).
Stone, Leander, 3352 Indiana Ave., Chicago, Ill. (32).
Stone, Lincoln R., M.D., Newton, Mass. (31).
Stone, Miss Mary H., Salem, Mass. (25).
Stone, Winthrop E., B.S., Amherst, Mass. (33). F C
Stowell, John, 48 Main St., Charlestown, Mass. (21).

Straight, Prof. H. H., Normal Park, Chicago, Ill. (25).
Strieby, Prof. William, Colorado Springs, Col. (31).
Sullivan, J. A., Malden, Mass. (27). A
Sullivan, James F., 1800 Spring Garden St., Philadelphia, Pa. (33).
Swasey, Oscar F., M.D., Beverly, Mass. (17).
Swathel, Miss Harriet M., Box 1764, Ann Arbor, Mich. (34). F

Tackabury, Geo. N., Canastota, N. Y. (34).
Tamari, Kizo, Agricultural College, Mich. (35).
Taylor, Clarence G., Ann Arbor, Mich. (34).
Taylor, Franklin, Philadelphia, Pa. (33).
Taylor, G. Morrison, 233 S. 4th St., Philadelphia, Pa. (33). E
Taylor, Comdr. H. C., U. S. N., Poughkeepsie, N. Y. (30).
Taylor, Prof. Jas. M., Hamilton, Madison Co., N. Y. (33). A D
Taylor, William, 912 New York Ave., Washington, D. C. (33). F H
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Thompson, Alton Howard, 237 Kansas Ave., Topeka, Kan. (33). H F
Thompson, Daniel G., 29 William St., New York, N. Y. (29).
Thompson, Mrs. Frank, Merion Station, Penn. R. R., Pa. (33).
Thompson, Miss Marie N., 323 Elm St., Cincinnati, Ohio (30). F H E
Thompson, Maurice, Crawsfordsville, Ind. (34). E F
Thomson, Prof. Harvey, Hastings, Neb. (35). F
Thorburn, John, LL.D., Ottawa, Ont., Can. (29). F H
Thornton, Prof. Wm. M., Univ. of Virginia, Va. (33). D A
Tiffany, Asa S., 901 West 5th St., Davenport, Scott Co., Iowa (27). E H
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Titsworth, Prof. Alfred A., Plainfield, N. J. (34). D A B
Tittmann, Otto H., U. S. Coast and Geodetic Survey Office, Washington, D. C. (24). A
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Townsend, David, 1723 Wallace St., Philadelphia, Pa. (33). D
Townsend, Mrs. David, 1723 Wallace St., Philadelphia, Pa. (33). F
Townsend, Franklin, 4 Elk St., Albany, N. Y. (4).
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Traphagen, Frank W., Ph.D., Staunton, Va. (35). C
Treat, Erastus B., Publisher and Bookseller, 771 Broadway, New York, N. Y. (29). F I
Treat, Mrs. Mary, Vineland, N. J. (33).
Trenholm, Hon. W. L., U. S. Comptroller of Currency, Washington, D C. (35).
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Trowbridge, Mrs. L. H., 266 Woodward Ave., Detroit, Mich. (21).
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Tucker, Willis G., M.D., Albany Medical Coll., Albany, N. Y. (29). C
Tullock, Alonzo J., Engineer, Leavenworth, Kansas (35). D
Turner, Henry Ward, U. S. Geol. Survey, San Francisco, Cal. (34). E
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Tyler, John M., Amherst, Mass. (29).

Vail, Prof. Hugh D., Santa Barbara, Cal. (18).
Valentine, Benj. B., Richmond, Va. (33). H
Valentine, Edw. P., Richmond, Va. (33). H
Vallandigham, James L., LL.D., Newark, Del. (33).
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Van Vleck, Frank, Instructor in Mechanism, Sibley College, Cornell Univ., Ithaca, N. Y. (35). D
Vasey, George, M.D., Dep't of Agric., Washington, D. C. (32). F
Vaughn, Dr. Victor C., Ann Arbor, Mich. (34). C
Vaux, Geo., jr., 1715 Arch St., Philadelphia, Pa. (33). E A
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Vredenburgh, Edw. H., Rochester, N. Y. (29).
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Wagner, Frank C., care Houston Electric Co., Lynn, Mass. (34). D
Waite, Dr. Henry R., President American Institute of Civics, Phillips Building, Hamilton Place, Boston, Mass. (35). I
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Wardwell, Geo. T., 235 Hudson St., Buffalo, N. Y. (35). E
Waring, Col. George E., jr., Newport, R. I. (29). I

Waring, John, Ovid, N. Y. (33). D B
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Warner, Worcester R., E. Prospect St., Cleveland, Ohio (33). A B D
Warren, Chas., M.D., 1208 N St., N. W., Washington, D. C. (31). H
Warren, Miss Lillie E., 26 W. 19th St., New York, N. Y. (35). H E
Warren, Samuel D., 220 Devonshire St., Boston, Mass. (29).
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Waterhouse, Ai, M.D., Jamestown, N. Y. (29). F
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Watkins, L. D., Manchester, Mich. (34).
Watson, Miss C. A., Salem, Mass. (31). D
Weaver, Lemuel, Urbana, Ohio (32).
Webb, Miss Sarah E., Elizabeth, N. J. (33). H F
Weber, Prof. Henry A., Ohio State Univ., Columbus. Ohio (35). F
Weeden, Hon. Joseph E., Randolph, N. Y. (31).
Weeks, Joseph D., Editor American Manufacturer, Pittsburgh, Pa. (35). D
Weitbrecht, George, 469 North St., St. Paul, Minn. (32). C E
Welch, Thomas V., Sup't State Reservation, Niagara Falls, N. Y. (35)
Wells, Mrs. C. F., 753 Broadway, New York, N. Y. (31). H F I D B
Wells, Rev. Martin L., Aurora, Ind. (30).
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Wendte, Rev. C. W., Newport, R. I. (29). H I
West, Arthur W., Salem, Mass. (31). D
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Wetherill, Miss J. J. (33).
Wheeler, Chas. F., Hubbardston, Ionia Co., Mich. (34). F E
Wheeler, Herbert A., Washington Univ., St. Louis, Mo. (33). E I
Wheeler, Moses D., M.E., Stapleton, Richmond Co., N. Y. (35). D
Wheeler, T. B., M.D., 714 Craig St., Montreal, Canada (11).
Wheildon, Miss Alice W., Concord, Mass. (31).
Whelen, Edw. S., Torrisdale P. O., Philadelphia, Pa. (33).
Whetstone, John L., Summit Ave., Mt. Auburn, Cincinnati, Ohio (30). D
Whitall, Henry, 1019 N. 3d St., Camden, N. J. (33). A E
White, Charles H., Surgeon U. S. N., Navy Dep't, Washington, D. C. (34). C
White, Prof. Charles Joyce, Cambridge, Mass. (29). A
White, Ernest William, 1634 S. Juniper St., Philadelphia, Pa. (33).
White, James G., Univ. of Neb., Lincoln, Neb. (34). B A

White, James W., M.D., Chestnut, S. E. cor. 12th St., Philadelphia, Pa. (33). H I
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White, LeRoy S., Box 324, Waterbury, Conn. (23).
Whiteaves, J. F., Geological Survey, Ottawa, Can. (31). E F
Whitehouse, F. Cope, Brevoort House, New York, N. Y. (31).
Whiting, S. B., Pottsville, Pa. (33). D
Whitman, Gilbert P., Manchester, N. H. (30).
Wicksteed, Richard John, LL.D., House of Commons, Ottawa, Province of Ont., Can. (29).
Wiechmann, F. G., School of Mines, Columbia College, New York, N. Y. (30). C E
Wight, Orlando W., M.D., Detroit, Mich. (34). H F
Wilbour, Mrs. Charlotte B., care J. M. Furley, 74 W. 35th St., New York, N. Y. (28).
Wilcox, Miss Emily T., 85 Second St., Troy, N. Y. (33). B A
Wilder, Alex., M.D., 565 Orange St., Newark, N. J. (29). H F I
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Wilkinson, Mrs. L. V., Seventy Six P. O., Perry Co., Mo. (30).
Willcox, Joseph, Media, Pa. (33).
Willetts, Joseph C., Skaneateles, N. Y. (29). E F H
Williams, Benezette, 171 La Salle St., Chicago, Ill. (33). D
Williams, Prof. Edward H., jr., Box 463, Bethlehem, Pa. (25). E D
Williams, H. Smith, Charles City, Iowa (34). F
Williams, J. Francis, Salem, N. Y. (31). C E
WILLIAMS, P. O., M.D., Watertown, Jefferson Co., N. Y. (24). A E
Wills, William R., Waltham, Mass. (30).
Willson, Prof. Frederick N., Princeton, N. J. (33). A F
Willson, Robert W., care Rev. E. B. Willson, Salem, Mass. (30). B A
Wilmot, Thos. J., Commercial Cable Co., Waterville, County Kerry, Ireland (27). B
Wilson, C. H., Belize, British Honduras (30). E C D
Wilson, Chas. M., M.D., 1517 Walnut St., Philadelphia, Pa. (33). F H
Wilson, J. M., State Normal School, Oshkosh, Wis. (33).
Wilson, Dr. James C., Corner 17th and Samson Sts., Philadelphia, Pa. (33). F
Wilson, M. C., Florence, Ala. (26).
Winchell, Horace V., 10 State St., Minneapolis, Minn. (34). E C
Wingate, Miss Hannah S., 208 Raymond St., Brooklyn, N. Y. (31). E I
Winston, Prof. Charles H., Richmond College, Richmond, Va. (30). B A D C
Wisser, John P., 1st Lt. 1st Art'y, U. S. A., West Point, N. Y. (33). C
Wister, Mrs. Caspar, 1303 Arch St., Philadelphia, Pa. (33).
Witherowe, James P., Pittsburgh, Pa. (33).
Withers, W. A., A.M., Agricultural Experiment Station, Raleigh, N. C. (33). C

Witthaus, Dr. R. A., University Med. Coll., New York, N. Y. (35).
Wolcott, Mrs. Henrietta L. T., Hotel Vendome, Boston, Mass. (29).
Wood, Alvinus B., Ann Arbor, Mich. (34). E
Wood, Harry A., M.D., State Insane Asylum, Buffalo, N. Y. (35).
WOOD, DR. ROBERT W., Jamaica Plain, Mass. (29).
WOOD, WALTER, 400 Chestnut St., Philadelphia, Pa. (33). F I
Woodward, Richard W., 10 College St., New Haven, Conn. (29). C
Wrampelmeier, Theo. J., Ann Arbor, Mich. (34). C
Wright, Harrison, Sec'y Wyoming Hist. and Geol. Soc., Wilkes Barre, Pa. (29).
Würtele, Miss Minnie, Acton Vale, P. Q., Can. (32). H
Wylie, Samuel B., Bloomington, Ind. (30). C B
Wylie, Rev. T. W. J., D.D., 1824 Wylie St., Philadelphia, Pa. (33).
Wyman, Waller C., 158 Dearborn St., Chicago, Ill. (34). H

Youmans, Wm. Jay, M.D., Popular Science Monthly, 1-5 Bond St., New York, N. Y. (28). F C
Young, Prof. A. Harvey, Hanover College, Hanover, Ind. (30). F C
Young, Albert B., 29 Park St., Buffalo, N. Y. (35).
Young, Chas. Ira, care Prof. C. A. Young, Princeton, N. J. (33). B F A

Zimmerman, William, 164 Dearborn St., Chicago, Ill. (30). F D B

[1255 MEMBERS.]

NOTE.—The omission of an address in the foregoing list indicates that letters directed to that last printed were returned as uncalled for. Information of the present address of the members so indicated is requested by the PERMANENT SECRETARY.

HONORARY FELLOWS.[1]

ROGERS, WILLIAM B., Boston, Mass. (1). 1881. (Died in 1882.)
MICHEL EUGÈNE CHEVREUL, Paris (35). 1886.

FELLOWS.[2]

Aaron, Eugene M., P. O. Box 916, Philadelphia, Pa. (33). 1886. **F**
Abbe, Professor Cleveland, Army Signal Office, Washington, D. C. (16). 1874. **B A**
Abbott, Dr. Chas. C., Trenton, N. J. (29). 1883. **F H**
Abbott, Miss Helen C. De S., 1509 Locust St., Philadelphia, Pa. (33). 1885. **C F**
Agnew, Dr. Cornelius R., 266 Madison Ave., New York, N. Y. (32). 1885. **F**
Alden, Prof. Geo. I., Worcester, Mass. (33). 1885. **D**
Alexander, John S., 1935 Arch St., Philadelphia, Pa. (20). 1874. **B C D**
Allen, Dr. Harrison, 117 S. 20th St., Philadelphia, Pa. (29). 1882. **F**
Allen, Joel A., American Museum of Natural History, Central Park, New York (18). 1875. **F**
Alvord, Henry E., C.E., Amherst, Mass. (29). 1882. **I**
Ammen, Daniel, Rear Admiral U. S. Navy, Beltsville, Md. (26). 1881. **E**
Anderson, Dr. Joseph, Waterbury, Conn. (29). 1883. **H**
Anthony, Prof. Wm. A., Cornell Univ., Ithaca, N. Y. (28). 1880. **B**
Arthur, J. C., Geneva, N. Y. (21). 1883. **F**
Ashburner, Charles A., 907 Walnut St., Philadelphia, Pa. (31). 1883. **E**
Ashburner, Wm., 1014 Pine St., San Francisco, Cal. (29). 1882. **E**
Atkinson, Edward, 31 Milk St., Boston, Mass. (29). 1881. **I D**
Atwater, Prof. W. O., Wesleyan Univ., Middletown, Conn. (29). 1882. **C**
Auchincloss, Wm. S., 209 Church St., Philadelphia, Pa. (29). 1886. **D A**
Austen, Peter T., Ph.D., Rutgers College, Lock Box No. 2, New Brunswick, N. J. (26). 1879. **C**
Ayres, Prof. Brown, Tulane University, New Orleans, La. (31). 1885. **B**
Ayres, Howard, Museum Comp. Zoology, Cambridge, Mass. (34). 1886. **F**

Babcock, S. Moulton, N. Y. Agricultural Experiment Station, Geneva, N. Y. (33). 1885. **C**
Bailey, Prof. W. W., Brown University, Providence, R. I. (18). 1874. **F**
Baird, Prof. S. F., Sec'y Smithsonian Inst., Washington, D. C. (1). 1875.
Baker, Frank, M.D., 326 C St., N. W., Washington, D. C. (31). 1886. **F H**

[1] See ARTICLE VI of the Constitution. [2] See ARTICLE IV of the Constitution.

*** The number in parenthesis indicates the meeting at which the member joined the Association; the date following is the year when made a Fellow; the black letters at end of line are those of the sections to which the fellow belongs.

When the name is given in small capitals, it designates that the Fellow is also a Life Member, and is entitled to the Annual Volume of Proceedings.

Baker, Marcus, Coast and Geodetic Survey Office, Washington, D. C. (30). 1882. **A**

BARKER, PROF. G. F., Univ. of Penn., Philadelphia, Pa. (13). 1875. **B C**

Barnard, Edward E., Observatory of Vanderbilt University, Nashville, Tenn. (26). 1883. **A**

Barnard, F. A. P., President Columbia College, New York, N. Y. (7). 1874. **B D I A F**

Barnes, Prof. Chas. R., 241 Columbia St., Lafayette, Ind. (33). 1885. **F**

Bartlett, Prof. Edwin J., Dartmouth College, Hanover, N. H. (28). 1883. **C**

Bartlett, John R., Commander U. S. N., Navy Dep't, Washington, D. C. (30). 1882. **E B**

Bassett, Homer F., Waterbury, Conn. (23). 1874. **F**

Batchelder, Dr. J. H., Salem, Mass. (18). 1874. **C D**

Batchelder, John M., 3 Divinity Avenue, Cambridge, Mass. (8). 1875. **B D I**

Bausch, Edward, Rochester, N. Y. (26). 1883. **A B C F**

Bayne, Herbert A., Ph.D., Royal Military College, Kingston, Ont., Can. (29). 1885. **C**

Beal, Prof. Wm. James, Agricultural College, Ingham Co., Mich. (24). 1880. **F**

Beardsley, Prof. Arthur, Swarthmore College, Swarthmore, Del. Co., Pa. (33). 1885. **D**

Beauchamp, Rev. Wm. M., Baldwinsville, N. Y. (34). 1886. **H**

Bebb, M. S., 926 Grant Ave., Rockford, Ill. (34). 1886. **F**

Bell, Dr. Alex. Graham, Scott Circle, 1500 Rhode Island Ave., Washington, D. C. (26). 1879. **B H I**

Bell, Alex. Melville, 1525 35th St., Washington, D. C. (31). 1885. **H**

Bell, Samuel N., Manchester, N. H. (7). 1874.

Beman, Wooster W., 11 So. 5th St., Ann Arbor, Mich. (34). 1886. **A**

Bessey, Prof. Charles E., Univ. of Nebraska, Lincoln, Neb. (21). 1880. **F**

Bethune, Rev. C. J. S., Trinity College School, Pt. Hope, Ont., Can. (18). 1875. **F**

Beyer, Dr. Henry G., U. S. N., U. S. National Museum, Washington, D. C. (31). 1884. **F**

Bickmore, Prof. Albert S., American Museum of Natural History, 8th Ave. and 77th St., Central Park, New York, N. Y. (17). 1880. **H**

Billings, John S., Surgeon U. S. A., Surg. General's Office, Washington, D. C. (32). 1883. **F H**

Blackham, George E., M.D., Dunkirk, N. Y. (25). 1883. **F**

Blake, Clarence J., M.D., 226 Marlborough St., Boston, Mass. (24). 1877. **B F**

Blake, Prof. Eli W., jr., Brown Univ., Providence, R. I. (15). 1874. **B**

Blake, Francis, Auburndale, Mass. (23). 1874. **B A**

Blake, Prof. John R., Greenwood, S. C. (29). 1884. **B A**

Boardman, Mrs. William D., 38 Kenilworth St., Roxbury, Mass. (28). 1885. **E H**

Boerner, Chas. G., Vevay, Ind. (29). 1886. **A B E**

BOLTON, DR. H. CARRINGTON, Trinity College, Hartford, Conn. (17). 1875. **C**

Bond, Geo. M., care of The Pratt & Whitney Co., Hartford, Conn. (33). 1885. **D**

Borden, Spencer, Fall River, Mass. (29). 1882. **B C I**

Bourke, John G., Capt. 3d Cavalry, U. S. A., care of Adj. Gen. U. S. A., Washington, D. C. (33). 1885. **H**

Bouvé, Thos. T., Boston Soc. Nat. Hist., Boston, Mass. (1). 1875. **E**

Bowditch, Prof. H. P., Jamaica Plain, Mass. (28). 1880. **F B H**

Bowditch, Henry I., M.D., 113 Boylston St., Boston, Mass. (2). 1875. **F H**

Bowser, Prof. E. A., Rutgers College, New Brunswick, N. J. (28). 1881.

Brackett, Prof. C. F., College of New Jersey, Princeton, N. J. (19). 1875. **B**

Brackett, Solomon H., St. Johnsbury, Vt. (29). 1884. **B A**

Branner, John C., Indiana Univ., Bloomington, Ind. (34). 1886. **E F**

Brashear, Jno. A., 3 Holt St., Pittsburgh, S. S., Pa. (33). 1885. **A B D**

Brewer, Prof. Wm. H., New Haven, Conn. (20). 1875. **E F I**

Brewster, William, 61 Sparks St., Cambridge, Mass. (29). 1884. **F**

Brinton, D. G., M.D., Media, Pa. (33). 1885. **H**

Britton, N. L., Columbia College, New York, N. Y. (29). 1882. **F E**

Broadhead, Garland Carr, Pleasant Hill, Cass Co., Mo. (27). 1879. **E**

Brooks, Wm. R., Phelps, N. Y. (35). 1886. **A**

Bross, Hon. Wm., Tribune Office, Chicago, Ill. (7). 1874. **E H**

Brown, Robert, care of Yale College Observatory, New Haven, Conn. (11). 1874.

Brown, Mrs. Robert, New Haven, Conn. (17). 1874.

Brühl, Gustav, cor. John and Hopkins Sts., Cincinnati, Ohio (28). 1886. **H**

Brush, Charles F., Brush Electric Light Co., Cleveland, Ohio (35). 1886. **B**

BRUSH, PROF. GEORGE J., Yale College, New Haven, Conn. (4). 1874. **C E**

Buckhout, W. A., State College, Centre Co., Pa. (20). 1881. **F**

Burnham, S. W., 3573 Vincennes Ave., Chicago, Ill. (25). 1877. **A**

Burr, Prof. William H., Phoenixville, Chester Co., Pa. (31). 1883.

Burrill, Prof. T. J., Univ. of Illinois, Champaign, Ill. (29). 1882. **F**

Butler, A. W., Brookville, Franklin Co., Ind. (30). 1885. **F H**

Caldwell, Prof. Geo. C., Cornell University, Ithaca, N. Y. (23). 1875. **C**

Canby, William M., 1101 Delaware Avenue, Wilmington, Del. (17). 1878. **F**

Carhart, Prof. Henry S., Michigan University, Ann Arbor, Mich. (29). 1881. **B A**

Carmichael, Prof. Henry, 55 Kilby St., Boston, Mass. (21). 1875. **C**

Carpenter, Lieut. W. L., U. S. A., Dunkirk, N. Y. (24). 1877. **F E**

Carpmael, Charles, Director of Magnetic Observatory, Toronto, Can. (31). 1883. **B**

Carr, Lucien, Peabody Museum Archæology and Ethnology, Cambridge, Mass. (25). 1877. **H**

Case, Col. Theo. S., Kansas City, Mo. (27). 1883. **H B**
Chamberlin, T. C., U. S. Geological Survey, Washington, D. C. (21). 1877. **E B F H**
Chandler, Prof. C. F., School of Mines, Columbia Coll., 50th St. cor. 4th Ave., New York, N. Y. (19). 1875. **C**
Chandler, Prof. Charles Henry, Ripon, Wis. (28). 1883. **A B**
Chandler, Seth C., jr., 16 Cragie St., Cambridge, Mass. (29). 1882. **A**
Chandler, Prof. W. H., South Bethlehem, Pa. (19). 1874. **C**
Chanute, O., Kansas City, Mo. (17). 1877. **D I**
Chapin, Dr. J. H., Meriden, Conn. (33). 1886. **E H**
Chase, Prof. Pliny E., Haverford College P. O., Pa. (18). 1884. **A B**
Chester, Prof. Albert H., Hamilton College, Clinton, N. Y. (29). 1882. **C F**
Chickering, Prof. J. W., jr., Deaf Mute College, Washington, D. C. (22). 1877. **F I**
Chittenden, Russell H., Ph.D., New Haven, Conn. (29). 1882. **C F**
Clapp, Miss Cornelia M., Mt. Holyoke Seminary, South Hadley, Mass. (31). 1883. **F**
Clark, Alvan G., Cambridgeport, Mass. (28). 1880. **A B**
Clark, Prof. John E., Mathematics, Yale College, New Haven, Conn. (17). 1875. **A**
Clarke, Miss Cora H., Jamaica Plain, Mass. (29). 1884. **F I**
Clarke, Prof. F. W., U. S. Geological Survey, Washington, D. C. (18). 1874. **C**
Claypole, Prof. Edw. W., Buchtel Coll., Akron, Ohio (30). 1882. **E F**
Cloud, John W., Altoona, Pa. (28). 1886. **A B D**
Coffin, Prof. John H. C., U. S. Navy, Washington, D. C. (1). 1874. **A**
Coffin, Prof. Selden J., Lafayette College, Easton, Pa. (22). 1874. **A I**
Collett, Prof. John, Newport, Ind. (17). 1874. **E**
Colvin, Verplanck, Supt. N. Y. State Adirondack Survey, Albany, N. Y. (28). 1880. **E**
Comstock, J. Henry, Cornell Univ., Ithaca, N. Y. (28). 1882. **F**
Comstock, Milton L., 641 Academy St., Galesburg, Ill. (21). 1874. **A**
Comstock, Prof. Theo. B., Prof. of Mining Engineering, Univ. of Illinois, Champaign, Ill. (24). 1877. **D E B**
Cook, Prof. A. J., Agricultural College, Mich. (24). 1880. **F**
Cook, Prof. George H., New Brunswick, N. J. (4). 1875. **E**
Cooley, Prof. Le Roy C., Vassar College, Poughkeepsie, N. Y. (19). 1880. **B C**
Cope, Prof. Edward D., 2100 Pine St., Philadelphia, Pa. (17). 1875. **F E**
Corthell, Elmer L., 34 Nassau St., Room 709, New York, N. Y. (34). 1886. **D**
Coulter, Prof. John M., Wabash College, Crawfordsville, Ind. (32). 1884. **F**
Cox, Prof. Edward T., New Harmony, Ind. (19). 1874. **E**
Cox, Hon. Jacob D., Gilman Ave., Mt. Auburn, Cincinnati, Ohio (30). 1881. **F**
Coxe, Eckley B., Drifton, Luzerne Co., Pa. (23). 1879. **D E**
Crandall, Prof. A. R., Lexington, Ky. (29). 1883. **E F**

Crocker, Susan E., M.D., Lawrence, Mass. (21). 1874. **E F**

Crosby, Prof. Wm. O., Boston Society of Natural History, Boston, Mass. (29). 1881. **E**

Cross, Prof. Chas. R., Mass. Institute Technology, Boston, Mass. (29). 1880. **B**

Cummings, Rev. Joseph, D.D., President Northwestern University, Evanston, Ill. (13). 1874. **I H**

Cutting, Hiram A., M.D., State Geologist, Lunenburgh, Vt. (17). 1874. **E F**

Dabney, Chas. W., jr., Ph.D., Agricultural Experiment Station, Raleigh, N. C. (30). 1882. **C B E**

Dall, Mrs. Caroline H., 1630 O St., Washington, D. C. (18). 1874. **F H**

Dall, William H., Smithsonian Institution, Washington, D. C. (18). 1874. **H F**

Dana, Edward Salisbury, New Haven, Conn. (23). 1875. **B E**

Dana, Prof. James D., New Haven, Conn. (1). 1875. **E**

Danforth, Edward, Department of Public Instruction, Elmira, N. Y. (11). 1874. **E I H A B**

Davenport, B. F., M.D., 751 Tremont St., Boston, Mass. (29). 1883. **C**

Davidson, Prof. Geo., Asst. U. S. Coast and Geodetic Survey, San Francisco, Cal. (29). 1881. **A B D**

Davis, Wm. Morris, Cambridge, Mass. (33). 1885. **E B**

Dawson, Sir William, Principal McGill College, Montreal, Can. (10). 1875. **E**

Day, F. H., M.D., Wauwatosa, Wis. (20). 1874. **E H F**

Dean, George W., P. O. Box 92, Fall River, Mass. (15). 1874. **A**

Dewey, Fred P., Ph.B., Smithsonian Institution, Washington, D. C. (30). 1886. **C E**

Diller, J. Silas, U. S. Geol. Survey, Washington, D. C. (29). 1884. **E**

Dimmock, George, Cambridge, Mass. (22). 1874. **F**

Dinwiddie, Robert, 117 W. 43d St., New York, N. Y. (1). 1874. **F**

Dodge, Prof. James A., University of Minnesota, Minneapolis, Minn. (29). 1884. **C E**

Dodge, J. Richards, Washington, D. C. (31). 1884. **I H**

Dolbear, A. Emerson, College Hill, Mass. (20). 1880. **B**

Doolittle, Prof. C. L., South Bethlehem, Pa. (25). 1885. **A**

Dorsey, Rev. J. Owen, Box 591, Washington, D. C. (31). 1883. **H**

Douglass, Andrew E., P. O. Box 605, New York, N. Y. (31). 1885. **H**

Dow, Capt. John M., 69 Seventh Ave., New York, N. Y. (31). 1884. **F H**

Draper, Dan'l, Ph.D., Director N. Y. Meteorological Observatory, Central Park, 64th St., Fifth Avenue, New York, N. Y. (29). 1881. **B D F A**

Drown, Prof. Thos. M., Mass. Institute Technology, Boston, Mass. (29). 1881. **C**

Du Bois, Prof. Aug. J., New Haven, Conn. (30). 1882. **A B D**

Dudley, Charles B., Altoona, Pa. (23). 1882. **C B D**

Dudley, P. H., 66½ Pine St., New York, N. Y. (29). 1884.

Dudley, Wm. L., Prof. of Chemistry, Vanderbilt Univ., Nashville, Tenn. (28). 1881. **C**

Dudley, Prof. Wm. R., Ithaca, N. Y. (29). 1883. **F**

Dun, Walter A., M.D., 70 E. 4th St., Cincinnati, Ohio (31). 1886. **H**

Dunnington, Prof. F. P., University of Virginia, Va. (26). 1880. **C**

Dwight, Prof. William B., Vassar College, Poughkeepsie, N. Y. (30). 1882. **E F**

Eads, Jas. B., 34 Nassau St., New York, N. Y. (27). 1879. **D**

Eastman, Prof. J. R., U. S. Naval Observatory, Washington, D. C. (26). 1879. **A**

Eaton, Prof. D. G., 55 Pineapple St., Brooklyn, N. Y. (19). 1874. **B E**

Eaton, Prof. James R., Liberty, Mo. (29). 1885. **C B E**

Eaton, Hon. John, President Marietta College, Marietta, Ohio (25). 1883. **I**

Eddy, Prof. H. T., Univ. of Cincinnati, Cincinnati, O. (24). 1875. **A B D**

Edison, Thos. A., Menlo Park, N. J. (27). 1878. **B**

Egleston, Prof. Thomas, 35 W. Washington Square, New York, N. Y. (27). 1879. **C D E**

Elkin, William L., Yale Coll. Observ., New Haven, Conn. (33). 1885. **A**

Elliott, Arthur H., School of Mines, Columbia College, New York, N. Y. (23). 1880. **C**

Elliott, Ezekiel B., Government Actuary, Treasury Dep't, Washington, D. C. (10). 1874. **I A B**

Ely, Theo. N., Sup't Motive Power, Penn. R. R., Altoona, Pa. (29). 1886.

Eimbeck, William, U. S. C. and G. S., Washington, D. C. (17). 1874. **A B D**

Emerson, Prof. Benjamin K., Amherst, Mass. (19). 1877. **E F**

Emerson, Prof. C. F., Dartmouth Coll., Hanover, N. H. (22). 1874. **B A**

Emerton, James H., New Haven, Conn. (18). 1875. **F**

Emery, Albert H., Stamford, Conn. (29). 1884. **D B**

Emery, Charles E., 22 Cortlandt St., New York, N. Y. (34). 1886. **D B A**

Emmons, S. F., U. S. Geol. Survey, Washington, D. C. (26). 1879. **E**

Engelmann, George J., M.D., 3003 Locust St., St. Louis, Mo. (25). 1875. **F H**

Evans, Asher B., 500 Pine St., Lockport, N. Y. (19). 1874. **A**

Fairbanks, Henry, Ph.D., St. Johnsbury, Vt. (14). 1874. **B D A**

Fairchild, H. L., Sec'y N. Y. Acad. Sciences, 102 E. 52d St., New York, N. Y. (28). 1883. **E F**

Fanning, John T., Union Depot, Minneapolis, Minn. (29). 1885. **D**

Farlow, Dr. W. G., 29 Holyoke House, Cambridge, Mass. (20). 1875. **F**

Farmer, Moses G., Torpedo Station, Newport, R. I. (9). 1875.

Farquhar, Henry, Coast Survey Office, Washington, D. C. (33). 1886. **A**

Fernald, Prof. Charles H., State Agricultural College, Orono, Me. (22). 1881. **F E**

Fernald, Prof. M. C., State Agric. College, Orono, Me. (22). 1883. **B A**

Ferrel, Wm., Army Signal Office, Washington, D. C. (11). 1875. **A B**

Ficklin, Prof. Joseph, Univ. of Missouri, Columbia, Mo. (20). 1878. **A B**

Fitch, Edward H., Jefferson, Ashtabula Co., Ohio (11). 1874. **I E**

Fletcher, Miss Alice C., care Peabody Museum, Cambridge, Mass. (29). 1883. **H**

Fletcher, Dr. Robert, Surgeon General's Office, U. S. A., Washington, D. C. (29). 1881. **F H**

Flint, James M., Surgeon U. S. N., Navy Dep't, Washington, D. C. (28). 1882. **F**

Foote, Dr. A. E., 1223 Belmont Ave., Philadelphia, Pa. (21). 1874. **E C**

Forbes, Prof. S. A., Univ. of Illinois, Champaign, Ill. (27). 1879. **F**

Fox, Prof. Joseph G., Lafayette College, Easton, Pa. (31). 1886. **A B**

Foye, Prof. J. C., Lawrence Univ., Appleton, Wis. (29). 1884. **C B**

FRAZER, DR. PERSIFOR, 917 Clinton St., Philadelphia, Pa. (24). 1879. **E C**

Frazier, Prof. B. W., The Lehigh Univ., Bethlehem, Pa. (24). 1882. **E C**

Frear, Wm., State College, Centre Co., Pa. (33). 1886. **C**

French, Prof. Thomas, jr., Ridgeway Ave., Avondale, Cincinnati, Ohio (30). 1883. **B**

Frisby, Prof. Edgar, U. S. N. Observ., Washington, D. C. (28). 1880. **A**

Fuller, Andrew S., Ridgewood, Bergen Co., N. J. (24). 1882. **F**

Gage, Simon Henry, Ithaca, N. Y. (28). 1881. **F**

Gannett, Henry, U. S. Geological Survey, Washington, D. C. (33). 1884. **E I A**

Gardiner, Rev. Frederic, D.D., Middletown, Conn. (23). 1874. **C B**

Gardiner, James T., Director N. Y. State Survey, Albany, N. Y. (25). 1879. **E**

Garland, Rev. Dr. L. C., Chancellor Vanderbilt University, Nashville, Tenn. (25). 1877. **B**

Garman, Samuel, Museum Comparative Zoology, Cambridge, Mass. (20). 1874. **F E**

Gatschet, Albert S., P. O. Box 591, Washington, D. C. (30). 1882. **H**

Genth, Dr. F. A., University of Pennsylvania, Philadelphia, Pa. (24). 1875. **C E**

Gibbs, Prof. J. Willard, New Haven, Conn. (33). 1885. **B**

Gilbert, G. K., Box 591, Washington, D. C. (18). 1874. **E**

Gillman, Henry, Detroit, Mich. (24). 1875. **H F**

Gilman, Daniel C., President Johns Hopkins University, Baltimore, Md. (10). 1875. **E H**

Goessman, Prof. C. A., Mass. Agric. Coll., Amherst, Mass. (18). 1875. **C**

Goldschmidt, S. A., Ph.D., 55 Broadway, New York, N. Y. (24). 1880. **C E B**

Gooch, Frank A., U. S. Geol. Survey, Washington, D. C. (25). 1880. **C**

Goodfellow, Edward, Ass't U. S. Coast and Geodetic Survey, Washington, D. C. (24). 1879. **A H**

Gould, Dr. B. A., Cambridge, Mass. (2). 1875. **A B**

Grant, Mrs. Mary J., Brookfield, Conn. (23). 1874. **A**

Gratacap, L. P., Ph.B., 77th St. and 8th Ave., New York, N. Y. (27). 1884. **C E F**

Gray, Prof. Asa, Botanic Gardens, Cambridge, Mass. (1). 1875. **F**

Gray, Elisha, Sc.D., Highland Park, Ill. (32). 1883. **B**
Green, Traill, M.D., Easton, Pa. (1). 1874. **C F**
Grimes, J. Stanley, 81 Randolph St., Chicago, Ill. (17). 1874. **E H**
Grinnan, A G., Rapidan Station, Va. Mid. R. R., Va. (7). 1875.
Grinnell, George Bird, 40 Park Row, New York, N. Y. (25). 1885. **F E**
Gulley, Prof. Frank A., Agricultural College, Oktibbeha Co., Miss. (30). 1883.

Hagen, Dr. Hermann A., Museum Comparative Zoology, Cambridge, Mass. (17). 1875. **F**
Hale, Albert C., Ph.D., Box 65, Brooklyn, N. Y. (29). 1886. **C B**
Hale, Horatio, Clinton, Ontario, Can. (30). 1882. **H**
Hall, Prof. Asaph, U. S. Naval Observ., Washington, D. C. (25). 1877. **A**
Hall, Prof. C. W., Univ. of Minnesota, Minneapolis, Minn. (28). 1883. **E**
Hall, Prof. Edwin H., 5 Avon St., Cambridge, Mass. (29). 1881. **B**
Hall, Prof. James, Albany, N. Y. (1). 1875. **E F**
Hall, Prof. Lyman B., Haverford College, Pa. (31). 1884. **C**
Halsted, Byron D., Agricultural College, Ames, Iowa (29). 1883. **F**
Hamlin, Dr. A. C., Bangor, Me. (10). 1874. **C E H**
HANAMAN, C. E., Troy, N. Y. (19). 1883. **F**
Hardy, Prof. A. S., Dartmouth College, Hanover, N. H. (28). 1883. **A**
Harger, Oscar, 14 University Place, New Haven, Conn. (25). 1879. **F E**
HARKNESS, PROF. WILLIAM, U. S. N. Observatory, Washington, D. C. (26). 1878. **A B C D**
Harrington, Prof. Mark W., Ann Arbor, Mich. (22). 1875. **A B**
Harris, Uriah R., Lieutenant U. S. N., Navy Yard, Mare Island, Cal. (34). 1886. **A**
Harrison, Dr. B. F., Wallingford, Conn. (11). 1874. **E C**
Hart, Edw., Ph.D., Easton, Pa. (33). 1885.
Hasbrouck, Prof. I. E., 364 Carlton Ave., Brooklyn, N. Y. (23). 1874. **D A I**
Hastings, C. S., Sheffield Scientific School of Yale College, New Haven, Conn. (25). 1878. **B**
Haupt, Prof. Lewis M., University of Pennsylvania, Philadelphia, Pa. (32). 1885. **I D E**
Haynes, Henry W., 239 Beacon St., Boston, Mass. (28). 1884. **H**
Hazen, Wm. B., Brig. and B'vt Maj. Gen'l, Chief Signal Officer, U. S. A., Washington, D. C. (30). 1882. **I**
Heilprin, Prof. Angelo, Acad. Nat. Sciences, Philadelphia, Pa. (33). 1885. **E F**
Hendricks, J. E., Des Moines, Iowa (29). 1885. **A**
Hering, Rudolph, 326 Walnut St., Philadelphia, Pa. (33). 1885. **D E I**
Hervey, Rev. A. B., Taunton, Mass. (22). 1879. **F**
Hicks, Prof. Lewis E., State University, Lincoln, Neb. (31). 1885. **E F**
Hilgard, Prof. E. W., University of California, Berkeley, Cal. (11). 1874. **C E B**
Hilgard, Prof. J. E., Washington, D. C. (4). 1874. **A**

Hill, Franklin C., P. O. Box 338, Princeton, N. J. (29). 1881. **E F**
Hill, Rev. Dr. Thomas, 738 Congress St., Portland, Me. (3). 1875. **A**
Himes, Prof. Charles F., Carlisle, Pa. (29). 1882. **B C**
Hitchcock, Prof. Charles H., Hanover, N. H. (11). 1874. **E**
Hitchcock, Romyn, Washington, D. C. (29). 1881. **C B**
Hobbs, A. C., Bridgeport, Conn. (28). 1886. **D**
Hodges, N. D. C., Editorial office of Science, 47 Lafayette St., New York, N. Y. (29). 1882. **B**
Hoffman, Dr. Fred., 183 Broadway, New York, N. Y. (28). 1881. **C F**
Holden, Prof. E. S., Lick Observatory, San José, Cal. (23). 1875. **A**
Holman, Silas W., Massachusetts Institute of Technology, Boston, Mass. (31). 1883. **B**
Holmes, Dr. Oliver Wendell, 296 Beacon St., Boston, Mass. (29). 1881. **H**
Holmes, Wm. H., Bureau of Ethnology, Smithsonian Institution, Washington, D. C. (30). 1883. **H**
Horsford, Prof. E. N., Cambridge, Mass. (1). 1876. **C E**
Hosea, Lewis M., Johnston Building; Cincinnati, Ohio (30). 1883.
Hotchkiss, Major Jed., Staunton, Va. (31). 1883. **E H I**
Hough, Prof. G. W., Director Dearborn Observatory, Chicago, Ill. (15). 1874. **A**
Hovey. Rev. Horace C., 1519 Park Avenue, Minneapolis, Minn. (29). 1883. **E H**
Hoy, Philo R., M.D., Racine, Wis. (17). 1875. **F H**
Hunt, George, Providence, R. I. (9). 1874.
Hunt, Dr. T. Sterry, Montreal, Canada (1). 1874. **C E**
Huntington, Prof. J. H., Boston, Mass. (19). 1874.
Hyatt, Prof. Alpheus, Natural History Society, Boston, Mass. (18). 1875. **E**
Hyatt, James, Stanfordville, Duchess Co., N. Y. (10). 1874. **I F E B**
Hyde, Prof. E. W., Walnut Hills, Cincinnati, Ohio (25). 1881. **A**

Iddings, Joseph P., U. S. Geol. Survey, Washington, D. C. (31). 1884. **E**
Irving, Roland D., Wis. State Geol. Survey, Madison, Wis. (26). 1879. **E**

James, Jos. F., Miami Univ., Oxford, Ohio (30). 1882. **F E**
Jayne, Horace F., 1826 Chestnut St., Philadelphia, Pa. (29). 1884. **F H**
Jeffries, B. Joy, M.D., 15 Chestnut St., Boston, Mass. (29). 1881. **F H**
Jenkins, Edw. H., New Haven, Conn. (33). 1885. **C**
Jenks, Elisha T., Middleborough, Mass. (22). 1874. **D**
Jenks, Prof. J. W. P., Middleborough, Mass. (2). 1874. **B**
Jewell, Theo. F., Commander U. S. N., Torpedo Station, Newport, R. I. (25). 1882. **B**
Jillson, Dr. B. C., Champaign, Ill. (14). 1881. **E H F**
Johnson, John B., Washington Univ., St. Louis, Mo. (33). 1886. **D**
Johnson, Otis C., Ann Arbor, Mich. (34). 1886. **C**
Johnson, Prof. S. W., 54 Trumbull St., New Haven, Conn. (22). 1874. **C**
Johnson, Prof. W. W., Naval Academy, Annapolis, Md. (29). 1881. **A**

Joy, Prof. Charles A., care F. Hoffmann, Stockbridge, Mass. (8). 1879.
Julien, A. A., School of Mines, Columbia Coll., New York, N. Y. (24). 1875. **E C**

Kedzie, Prof. Robert C., Agricultural College, Mich. (29). 1881. **C**
Kellicott, David S., 119 Fourteenth St., Buffalo, N. Y. (31). 1883. **F**
Kendall, Prof. E. Otis, 3826 Locust St., Philadelphia, Pa. (29). 1882. **A**
Kent, William, 26 Highland Ave., Jersey City, N. J. (26). 1881. **D I**
Kershner, Prof. Jefferson E., Lancaster City, Pa. (29). 1883. **A B**
Kingsley, J. Sterling, Malden, Mass. (33). 1886. **F**
Kinnicutt, Leonard P., 5 Chestnut St., Worcester, Mass. (28). 1883. **C**
Kirkwood, Prof. Daniel, Bloomington, Ind. (7). 1874. **A**
Kolbe, C. W., Ph.D., 32 Longwood Ave., Cleveland, Ohio (33). 1885. **C**
Kunz, G. F., with Tiffany & Co., New York, N. Y. (29). 1883. **E H C**

LaFlesche, Francis, Indian Bureau, Interior Dep't, Washington, D. C. (33). 1885. **H**
Lambert, Rev. Thomas R., D.D., Charlestown, Mass. (18). 1874.
Landreth, Prof. Olin H., Vanderbilt Univ., Nashville, Tenn. (28). 1883. **D**
Langdon, Dr. F. W., 65 West 7th St., Cincinnati, Ohio (30). 1882. **F H**
Langley, Prof. J. W., Univ. of Mich., Ann Arbor, Mich. (23). 1875. **C B**
Langley, Prof. S. P., Director of Observatory, Allegheny, Pa. (18). 1874. **A B**
Lanza, Prof. Gaetano, Mass. Institute of Technology, Boston, Mass. (29). 1882. **D A B**
Larkin, Edgar L., New Windsor, Mercer Co., Ill. (28). 1883. **A**
Larkin, Ethan Pendleton, Ph.D., Alfred University, Alfred Centre, N. Y. (33). 1886. **F E**
Lattimore, Prof. S. A., University of Rochester, Rochester, N. Y. (15). 1874. **C**
Lawrence, George N., 45 E. 21st St., New York, N. Y. (7). 1877. **F**
Lazenby, Prof. Wm. R., Columbus, Ohio (30). 1882. **B I**
LeConte, Prof. Joseph, Univ. of Cal., Berkeley, Cal. (29). 1881. **E F**
Ledoux, Albert R., Ph.D., 10 Cedar St., New York, N. Y. (26). 1881. **C**
Leeds, Prof. Albert R., Stevens Institute, Hoboken, N. J. (23). 1874. **C F**
Lehman, G. W., Ph.D., 57 S. Gay St., Baltimore, Md. (30). 1885. **C B**
Leonard, N. R., State Univ., Iowa City, Iowa (21). 1875. **A B**
Lesley, Prof. J. Peter, State Geologist of Pennsylvania, 1008 Clinton St., Philadelphia, Pa. (2). 1874. **E**
Lewis, Prof. H. Carvill, High St., Germantown, Pa. (26). 1880. **E**
LILLY, GEN. WM., Mauch Chunk, Carbon Co., Pa. (28). 1882. (Patron). **F E**
Lintner, J. A., N. Y. State Entomologist, Room 27, Capitol, Albany, N. Y. (22). 1874. **F**
Litton, Abram, 2220 Eugenia St., St. Louis, Mo. (28). 1879. **C**
Lockwood, Rev. Samuel, Freehold, Monmouth Co., N. J. (18). 1875. **F B A**

Loomis, Prof. Elias, New Haven, Conn. (1). 1874. **A B**

Lord, Prof. Nat. W., State Univ., Columbus, Ohio (29). 1881. **C**

Loudon, Prof. James, Toronto, Can. (25). 1881. **B A**

Loughridge, Prof. R. H., South Carolina College, Columbia, S. C. (21). 1874. **E C**

Love, Edward G., School of Mines, Columbia College, New York, N. Y. (24). 1882. **C**

Lovering, Prof. Joseph, Harvard University, Cambridge, Mass. (2). 1875. **B A**

Lull, Edward P., Captain U. S. N., care Navy Dep't, Washington, D. C. (28). 1880. **E H**

Lupton, Prof. N. T., Auburn, Ala. (17). 1874. **C**

Lyle, David Alexander, Capt. of Ordnance U. S. A., Box 2253, Boston, Mass. (28). 1880. **D**

Lyman, Prof. Chester S., 88 Trumbull St., New Haven, Conn. (4). 1875. **A**

Lyman, Hon. Theodore, Brookline, Mass. (23). 1875. **F**

Lyon, Dr. Henry, 34 Monument Sq., Charlestown, Mass. (18). 1874.

McAdams, Wm., Alton, Ill. (27). 1885. **E H**

McGee, W. J., U. S. Geol. Survey, Washington, D. C. (27). 1882. **E**

McMurtrie, William, Univ. of Illinois, Champaign, Ill. (22). 1874. **C**

McNeill, Malcolm, Princeton, N. J. (32). 1885. **A**

McRae, Hamilton S., Sup't of Schools, Marion, Ind. (20). 1874. **H I**

Mabery, Prof. C. F., Case School of Applied Science, Cleveland, Ohio (29). 1881. **C**

Macfarlane, A., Univ. of Texas, Austin, Texas (34). 1886. **B A**

Mackintosh, James B., Lehigh Univ., So. Bethlehem, Pa. (27). 1883. **C B**

Macloskie, Prof. George, College of New Jersey, Princeton, N. J. (25). 1882. **F**

Mallery, Brevet Lieut. Col. Garrick, U. S. Army, Bureau of Ethnology, Washington, D. C. (26). 1879. **H**

MANN, B. PICKMAN, U. S. Department of Agriculture, Washington, D. C. (22). 1874. **I F**

Marcy, Oliver, LL.D., Evanston, Ill. (10). 1874. **E**

MARSH, PROF. O. C., Yale College, New Haven, Conn. (15). 1874. **F H**

Martin, Prof. Daniel S., 236 West 4th St., New York, N. Y. (23). 1879. **E F**

Martin, Prof. H. Newell, Johns Hopkins University, Baltimore, Md. (27). 1880. **F H**

Martin, Miss Lillie J., High School, Indianapolis, Ind. (32). 1886. **F C**

Martin, Prof. Wm. J., Davidson College, N. C. (31). 1884. **C E**

Mason, Prof. Otis T., National Mus., Washington, D. C. (25). 1877. **H**

Mason, Dr. William P., Troy, N. Y. (31). 1886. **C B**

Maxwell, Rev. Geo. M., Wyoming, Hamilton Co., Ohio (30). 1886. **H E**

Mayer, Prof. A. M., South Orange, N. J. (19). 1874.

Meehan, Thomas, Germantown, Pa. (17). 1875. **F**

Mees, Carl Leo, Columbus, Ohio (24). 1876. **B C**

Mendenhall, Prof. T. C., U. S. Signal Service, Washington, D. C. (20). 1874. **B**

Merriam, C. Hart, M.D., Washington, D. C. (33). 1835. **F**

Merriman, C. C., Rochester, N. Y. (29). 1880. **F**

Merriman, Prof. Mansfield, Lehigh University, Bethlehem, Pa. (32). 1885 **A D**

Metz, Charles L., M.D., Madisonville, Hamilton Co., Ohio (30). 1885. **H**

Michelson, A. A., Master U. S. N., 7 Rockwell St., Cleveland, Ohio (26). 1879. **B**

Mills, T. Wesley, Montreal, Can. (31). 1886. **F**

Minot, Dr. Charles Sedgwick, 25 Mt. Vernon St., Boston, Mass. (28). 1880. **F**

Minot, Francis, M.D., 65 Marlborough St., Boston, Mass. (29). 1884.

Mitchell, Miss Maria, Vassar College, Poughkeepsie, N. Y. (4). 1874.

Moore, Prof. J. W., M.D., Lafayette College, Easton, Pa. (22). 1874. **B D A**

Morley, Prof. Edward W., 749 Republic St., Cleveland, Ohio (18). 1876. **C B E**

Morris, Rev. John G., Baltimore, Md. (12). 1874.

Morse, Prof. E. S., Salem, Mass. (18). 1874. **F H**

Morton, H., Stevens Institute Technology, Hoboken, N. J. (18). 1875. **B C**

Moses, Prof. Thos. F., Urbana Univ., Urbana, Ohio (25). 1883. **H F**

Munroe, Prof. C. E., Chemist to Bureau of Ordnance, U. S. Torpedo Station, Newport, R. I. (22). 1874. **C**

Murdoch, John, Smithsonian Institution, Washington, D. C. (29). 1886. **F H**

Murdock, J. B., Lieut. U. S. N., 24 Alaska St., Roxbury, Mass. (28). 1885. **B**

Murtfeldt, Miss Mary E., Kirkwood, Mo. (27). 1881. **F**

Nason, Prof. H. B., Rensselaer Polytechnic Institute, Troy, N. Y. (13). 1874. **C E**

Nelson, Prof. A. B., Centre College, Danville, Ky. (30). 1882. **A B D**

Nelson, Prof. Edward T., Delaware, Delaware Co., Ohio (24). 1877. **E F**

Newberry, Prof. J. S., Columbia College, New York, N. Y. (5). 1875. **E F H I**

Newcomb, Prof. S., Navy Dep't, Washington, D. C. (13). 1874. **A B**

Newton, Hubert A., New Haven, Conn. (6). 1874. **A**

Nichols, E. L., Ph.D., Univ. of Kansas, Lawrence, Kansas (28). 1881. **B C**

Niles, Prof. W. H., Cambridge, Mass. (16). 1874.

Nipher, Prof. F. E., Washington Univ., St. Louis, Mo. (24). 1876. **B**

Norton, Lewis M., Ph.D., Mass. Institute of Technology, Boston, Mass. (29). 1884. **C**

Noyes, Prof. Wm. A., Rose Polytechnic Inst., Terre Haute, Ind. (32). 1885. **C**

Oliver, Dr. Charles A., M.D., 1507 Locust St., Philadelphia, Pa. (33). 1886. **F H B**

Oliver, Prof. James E., P. O. Box 1566, Ithaca, N. Y. (7). 1875. **A B I**

Oliver, Miss Mary E., Cascadilla Hotel, Ithaca, N. Y. (20). 1874. **H**

Ordway, Prof. John M., Tulane Univ., New Orleans, La. (9). 1875. **C**

Orton, Prof. Edward, President Ohio Agricultural and Mechanical College, Columbus, Ohio (19). 1875. **E**

Osborn, Henry F., S.D., Princeton, N. J. (29). 1883.

Osborn, Herbert, Ames, Iowa (32). 1884. **F**

Osborne, J. W., 212 Delaware Ave. N. E., Washington, D. C. (22). 1874. **D C B**

Osler, Prof. William, McGill College, Montreal, Canada (28). 1881. **F**

Owen, Dr. Richard, New Harmony, Ind. (20). 1874. **E**

Owens, Mrs. Mary E., 270 W. 7th St., Cincinnati, Ohio (30). 1885. **C**

Packard, Dr. A. S., 115 Angell St., Providence, R. I. (16). 1875. **F E**

Paine, Cyrus F., 242 East Ave., Rochester, N. Y. (12). 1874. **B A**

Paine, Nathaniel, Worcester, Mass. (18). 1874. **H**

Palfray, Hon. Charles W., Salem, Mass. (21). 1874.

Parke, John G., Lt. Col. Corps of Eng'rs, Bv't Maj. Gen. U. S. A., Office of Chief of Engineers, Washington, D. C. (29). 1881. **D**

Parkhurst, Henry M., Law Stenographer, 25 Chambers St., New York, N. Y. (23). 1874. **A**

Paul, Prof. Henry M., U. S. Naval Observatory, Washington, D. C. (33). 1885. **A B**

Payne, Prof. Wm. W., Carleton College Observatory, Northfield, Minn. (30). 1883. **A**

Peabody, Seline H., Regent University of Illinois, Champaign, Ill. (17). 1885. **D B F**

Peckham, S. F., 159 Olney St., Providence, R. I. (18). 1875. **C B E**

Pedrick, Wm. R., Lawrence, Mass. (22). 1875.

Peet, Rev. Stephen D., Clinton, Wis. (24). 1881. **H**

Peirce, Benj. O., jr., Ass't Prof., Harvard College, Cambridge, Mass. (29). 1886. **A B**

Penhallow, Prof. D. P., McGill College, Montreal, Can. (30). 1882. **F**

Perkins, Prof. George H., Burlington, Vt. (17). 1882. **H F E**

Peter, Dr. Robert, Kentucky Geol. Survey, Lexington, Ky. (29). 1881. **C**

Pettee, Prof. William H., Ann Arbor, Mich. (24). 1875. **E**

Phillips, A. W., New Haven, Conn. (24). 1879.

Phippen, Geo. D., Salem, Mass. (18). 1874. **F**

Pickering, Prof. E. C., Director of Observatory, Cambridge, Mass. (18). 1875. **A B**

Pickering, William H., Inst. Technology, Boston, Mass. (29). 1883. **B A**

Pike, Dr. William H., University College, Toronto, Can. (29). 1881.

Pilling, James C., Box 591, Washington, D. C. (28). 1882. **F H I**

Pillsbury, Prof. John H., Smith College, Northampton, Mass. (23). 1885. **F H**

Platt, Franklin, Ass't Geologist, 2nd Geol. Survey of Pa., 615 Walnut St., Philadelphia, Pa. (27). 1882. **E**

Pohlman, Dr. Julius, Buffalo, N. Y. (32). 1884. **E F**

Potter, Prof. William B., Washington Univ., St. Louis, Mo. (25). 1879.

Powell, Major J. W., U. S. Geologist, 910 M St. N. W., Washington, D. C. (23). 1875. **E H**

Prentiss, D. Webster, M.D., 1224 9th St. N. W., Washington, D. C. (29). 1882. **F**

Prescott, Prof. Albert B., Ann Arbor, Mich. (23). 1875. **C**

Pritchett, Henry S., Observatory Washington University, St. Louis, Mo. (29). 1881. **A**

Pulsifer, Wm. H., St. Louis, Mo. (26). 1879. **A H**

Putnam, F. W., Curator Peabody Museum American Archæology and Ethnology, Cambridge, Mass. (Address as Permanent Secretary A. A. A. S., Salem, Mass). (10). 1874. **H**

Quincy, Edmund, 88 Clinton St., Boston, Mass. (11). 1874.

Rauch, Dr. John H., Chicago, Ill. (11). 1875.

Raymond, Rossiter W., 17 Burling Slip, New York, N. Y. (15). 1875. **E I**

Redfield, J. H., care A. Whitney & Sons, Philadelphia, Pa. (1). 1874. **F**

Reed, E. Baynes, London, Ontario, Can. (27). 1882.

Rees, Prof. John K., Columbia College, New York, N. Y. (26). 1878. **A E B**

Remsen, Prof. Ira, Johns Hopkins Univ., Baltimore, Md. (22). 1875. **C**

Rice, John M., U. S. Naval Academy, Annapolis, Md. (25). 1881. **A D**

Rice, Prof. Wm. North, Wesleyan University, Middletown, Conn. (18). 1874. **E F**

Richards, Prof. Charles B., 43 Elm St., New Haven, Conn. (33). 1885. **D**

Richards, Edgar, Dep't of Agric., Washington, D. C. (31). 1886. **C**

Richards, Prof. Robert H., Mass. Inst. Tech., Boston, Mass. (22). 1875. **D**

Richards, Mrs. Robert H., Prof. Mass. Inst. of Tech., Boston, Mass. (23). 1878. **C**

Richardson, Clifford, Dep't of Agric., Washington, D. C. (30). 1884. **C**

Ricketts, Pierre de Peyster, Ph.D., School of Mines, Columbia College, New York, N. Y. (26). 1880. **C D E**

RILEY, PROF. C. V., U. S. Entomologist, 1700 13th St. N. W., Washington, D. C. (17). 1874. **F H I**

Ritchie, E. S., 87 Franklin St., Boston, Mass. (10). 1877. **B**

Roberts, Prof. Isaac P., Ithaca, N. Y. (33). 1886. **I**

Robinson, Prof. S. W., Univ. of Ohio, Columbus, Ohio (30). 1883. **D B A**

Rockwell, Gen. Alfred P., 3 Fairfield St., Boston, Mass. (10). 1882. **E**

Rockwell, Chas. H., Box 293, Tarrytown, N. Y. (28). 1883. **A D**

Rockwood, Prof. Charles G., jr., College of New Jersey, Princeton, N. J. (20). 1874. **A E B D**

Rogers, Fairman, 202 West Rittenhouse Square, Philadelphia, Pa. (11). 1874.

Rogers, Prof. W. A., Colby Univ., Waterville, Me. (15). 1875. **A B D**
Rominger, Dr. Carl, Ann Arbor, Mich. (21). 1879. **E**
Rood, Prof. O. N., Columbia College, New York, N. Y. (14). 1875. **B**
Rosenspitz, Dr. Alexander, Rabbi, Lock Box 688, Jacksonville, Fla. (26). 1883. **F E H**
Ross, Waldo O., 189 Devonshire St., Boston, Mass. (29). 1882.
Rowland, Prof. Henry A., Baltimore, Md. (29). 1880.
Runkle, Prof. J. D., Mass. Inst. of Tech., Boston, Mass. (2). 1875. **A D**
Rutherford, Lewis M., 175 Second Ave., New York, N. Y. (13). 1875.

Sadtler, Prof. Sam'l P., Univ. of Pa., Philadelphia, Pa. (22). 1875. **C**
• Safford, Dr. James M., Nashville, Tenn. (6). 1875. **E C F**
Salmon, Daniel E., Dep't of Agric., Washington, D. C. (31). 1885. **F**
Sampson, Commander W. T., U. S. N., Torpedo Station, Newport, R. I. (25). 1881. **B A**
Sanborn, Jeremiah Wilson, Agric. Coll., Columbia, Mo. (31). 1886.
Sanborn, Rev. John W., Albion, N. Y. (33). 1886. **H**
Saunders, William, London, Ontario, Canada (17). 1874. **F**
Schaeberle, J. M., Ann Arbor, Mich. (34). 1886.
Schanck, Prof. J. Stillwell, Princeton, New Jersey (4). 1882. **C B H**
Schott, Charles A., U. S. Coast and Geodetic Survey Office, Washington, D. C. (8). 1874. **A**
Schweitzer, Prof. Paul, State University of Missouri, Columbia, Mo. (24). 1877. **C B**
SCUDDER, SAMUEL H., Cambridge, Mass. (13). 1874. **F**
Seaman, W. H., Microscopist, 1424 11th St. N. W., Washington, D. C. (23). 1874. **C F**
Sedgwick, Prof. Wm. T., Mass. Inst. of Technology, Boston, Mass. (33). 1886. **F**
See, Horace, 1230 Spruce St., Philadelphia, Pa. (34). 1886. **D**
Seiler, Carl, M.D., 1346 Spruce St., Philadelphia, Pa. (29). 1882. **F B**
Sewall, Prof. Henry, Univ. of Mich., Ann Arbor, Mich. (34). 1885. **F**
Sharples, Stephen P., 13 Broad St., Boston, Mass. (29). 1884. **C**
Sheafer, P. W., Pottsville, Pa. (4). 1879. **E**
Sias, Solomon, M.D., Schoharie, Schoharie Co., N. Y. (10). 1874.
Sigsbee, Chas. D., Comd'r U. S. N., care of Navy Dep't, Washington, D. C. (28). 1882. **D E**
Sill, Hon. Elisha N., Cuyahoga Falls, Ohio (6). 1874.
Silliman, Prof. Justus M., Lafayette Coll., Easton, Pa. (19). 1874. **D E**
Skinner. Joseph J., Ithaca, N. Y. (23). 1880. **B**
Smiley, Charles W., U. S. Fish Commission, Washington, D. C. (28). 1883. **I**
Smith, Prof. Charles J., 35 Adelbert St., Cleveland, Ohio (32). 1885.
Smith, Edwin, Ass't U. S. Coast and Geodetic Survey, Washington, D. C. (30). 1882. **A B**
Smith, Prof. Eugene A., University of Alabama, Tuscaloosa, Ala. (20). 1877. **E C**

Smith, Prof. Francis H., University of Virginia, Charlottesville, Va. (26). 1880. **B A**

Smith, John B., National Museum, Washington, D. C. (32). 1884. **F**

SMITH, QUINTIUS C., M.D., No. 704 Congress Ave., Austin, Texas (26). 1881. **F**

Smith, Prof. S. I., Yale College, New Haven, Conn. (18). 1875. **F**

Smock, Prof. John Conover, New York State Museum, Albany, N. Y. (23). 1879. **E**

Snow, Prof. F. H., Lawrence, Kan. (29). 1881. **F E**

Snyder, Prof. Monroe B., High School Observatory, Philadelphia, Pa. (24). 1882. **A B**

Soule, R. H., Frankfort, N. Y. (33). 1886. **D**

Spalding, Volney M., Ann Arbor, Mich. (34). 1886. **F.**

Spencer, Prof. J. William, University of Missouri, Columbia, Mo. (28). 1882. **E**

Springer, Dr. Alfred, Box 579, Cincinnati, Ohio (24). 1880. **C**

Stallo, J. B., Masonic Temple, Cincinnati, Ohio (30). 1882.

Stearns, R. E. C., care Smithsonian Institution, Washington, D. C. (18). 1874. **F**

Steiner, Dr. Lewis H., Enoch Pratt Free Library, Baltimore, Md. (7). 1874. **I**

STEPHENS, W. HUDSON, Lowville, N. Y. (18). 1874. **E H**

Sternberg, George M., Surgeon U. S. A., Johns Hopkins Univ., Baltimore, Md. (24). 1880. **F**

Stevens, W. LeConte, 170 Joralemon St., Brooklyn, N. Y. (29). 1882. **B A C**

Stevenson, James, Ass't Ethnologist, Washington, D. C. (29). 1885. **H**

Stockwell, John N., 1008 Case Avenue, Cleveland, Ohio (18). 1875. **A**

Stone, George H., Colorado Springs, Col. (29). 1882. **E F**

Stone, Mrs. Leander, 3417 Indiana Avenue, Chicago, Ill. (22). 1874. **F E**

Stone, Ormond, Director Leander McCormick Observatory, University of Virginia, Va. (24). 1876. **A**

Storrs, Henry E., Jacksonville, Ill. (20). 1874. **C E**

Story, Wm. E., Johns Hopkins Univ., Baltimore, Md. (29). 1881. **A**

Stowell, Prof. T. B., Cortland, N. Y. (28). 1885. **F**

Stringham, Prof. Irving, Univ. of Cal., Berkeley, Cal. (33). 1885. **A**

Stuart, Prof. A. P. S., Lincoln, Nebraska (21). 1874. **C**

Sturtevant, E. Lewis, M.D., Geneva, N. Y. (29). 1882. **F**

Swift, Lewis, Ph.D., Rochester, N. Y. (29). 1882. **A**

Tainter, Sumner, 2020 F St. N. W., Washington, D. C. (29). 1881. **B D A**

Taylor, Thos., M.D., Dep't of Agric., Washington, D. C. (29). 1885. **F C**

Taylor, William B., Smithsonian Institution, Washington, D. C. (29). 1881. **B A**

Thomas, Benj. F., Ph.D., State Univ., Columbus, Ohio (29). 1882. **B A**

Thomson, Wm., M.D., 1426 Walnut St., Philadelphia, Pa. (33). 1885. **B**

Thurston, Prof. R. H., Sibley College, Cornell University, Ithaca, N. Y. (23). 1875. **D**

Todd, Prof. David P., Director Lawrence Observatory, Amherst College, Amherst, Mass. (27). 1881. **A B D**

Todd, Prof. James E., Tabor, Fremont Co., Iowa (22). 1886. **E F**

Townshend, Prof. N. S., Ohio State Univ., Columbus, Ohio (17). 1881. **F H**

Tracy, Sam'l M., Columbia, Boone Co., Mo. (27). 1881. **F**

Trembley, J. B., M.D., 952 8th St., Oakland, Alameda Co., Cal. (17). 1880. **B F**

Trowbridge, Prof. John, Harvard University, Cambridge, Mass. (25). 1876. **B**

Trowbridge, Prof. W. P., New Haven, Conn. (10). 1874. **D**

Trumbull, Dr. J. Hammond, Hartford, Conn. (29). 1882. **H**

Tuttle, Prof. Albert H., State University, Columbus, Ohio (17). 1874. **F**

Uhler, Philip R., 218 W. Hoffman St., Baltimore, Md. (19). 1874. **F E**

Underwood, Prof. Lucien M., 214 East Genesee St., Syracuse, N. Y. (33). 1885. **F**

Upham, Warren, 21 Newbury St., Somerville, Mass. (25). 1880. **E**

Upton, Winslow, Brown Univ., Providence, R. I. (29). 1883. **A**

Van der Weyde, P. H., M.D., Box 3619, New York, N. Y. (17). 1874. **B**

Van Dyck, Prof. Francis Cuyler, New Brunswick, N. J. (28). 1882. **B C F**

Van Vleck, Prof. John M., Middletown, Conn. (23). 1875. **A**

Very, Samuel W., Lieut. U. S. N., U. S. Torpedo Station, Newport, R. I. (28). 1886. **A B**

Vogdes, A. W., 1st Lt. 5th Art'y U. S. A., The Military Service Inst., Governor's Island, N. Y. (32). 1885. **E F**

Wachsmuth, Charles, 111 Marietta St., Burlington, Iowa (30). 1884. **E F**

Wadsworth, M. Edward, Ph.D., Colby University, Waterville, Me. (23). 1874. **E**

Walcott, Charles D., Nat'l Museum, Washington, D. C. (25). 1882. **E F**

Waldo, Leonard, S.D., Yale College Observatory, New Haven, Conn. (28). 1880. **A**

Walker, J. R., D.D.S., Bay Saint Louis, Hancock Co., Miss. (19). 1874. **E F H D B**

Wallace, Wm., Ansonia, Conn. (28). 1882.

WALLER, E., School of Mines, Columbia College, New York, N. Y. (23). 1874.

Walling, H. F., 98 Trowbridge St., Cambridge, Mass. (16). 1874. **E D A B**

Walmsley, W. H., 1016 Chestnut St., Philadelphia, Pa. (28). 1883. **F**

Ward, Prof. Henry A., Rochester, N. Y. (13). 1875. **F E H**

Ward, Lester F., U. S. Geological Survey, Washington, D. C. (26). 1879. **E F**.

Ward, Dr. R. H., 53 Fourth St., Troy, N. Y. (17). 1874. **F**

Warder, Prof. Robert B., Lafayette, Ind. (19). 1881. **C B**

WARNER, JAMES D., 199 Baltic St., Brooklyn, N. Y. (18). 1874. **A B**

Warren, Cyrus M., Brookline, Mass. (29). 1882. **C**

Warren, Dr. Joseph W., 107 Boylston St., Boston, Mass. (31). 1886. **F**

Warren, Prof. S. Edward, Newton, Mass. (17). 1875. **A–I**

Watson, Sereno, Botanic Gardens, Cambridge, Mass. (22). 1875. **F**

WATSON, PROF. WM., 107 Marlborough St., Boston, Mass. (12). 1884. **A**

Wead, Prof. Charles K., Malone, N. Y. (23). 1880. **B**

Webb, Prof. J. Burkitt, Stevens Inst., Hoboken, N. J. (31). 1883. **D B A**

Webster, Prof. N. B., Principal Webster Inst., Norfolk, Va. (7). 1874. **B C E**

Wells, Daniel H., Hartford, Conn. (18). 1875. **A I**

Westcott, O. S., Maywood, Cook Co., Ill. (21). 1874. **H F A**

Wheatland, Dr. Henry, President Essex Inst., Salem, Mass. (1). 1874.

Wheeler, Prof. C. Gilbert, 81 Clark St., Chicago, Ill. (18). 1883. **C E**

Wheeler, Orlando B., 1415 Washington Ave., St. Louis, Mo. (24). 1882. **A D**

Wheildon, W. W., Box 229, Concord, Mass. (13). 1874. **B E**

Whitaker, Channing, Box 524, Lowell, Mass. (29). 1886.

White, Prof. C. A., Le Droit Park, Washington, D. C. (17). 1875. **E F**

White, Prof. H. C., Univ. of Georgia, Athens, Ga. (29). 1885. **C**

White, Prof. I. C., Univ. of W. Va., Morgantown, W. Va. (25). 1882. **E**

Whitfield, R. P., American Museum Natural History, 77th St. & 8th Avenue, New York, N. Y. (18). 1874. **E F H**

Whiting, Miss Sarah F., Wellesley College, Wellesley, Mass. (31). 1883. **B A**

Whitman, Prof. Frank P., Rensselaer Polytechnic Inst., Troy, N. Y. (33). 1885.

Wilber, G. M., Pine Plains, N. Y. (19). 1874. **F H**

Wilder, Prof. Burt G., Cornell University, Ithaca, N. Y. (22). 1875. **F**

Wiley, Prof. Harvey W., Dep't of Agric., Washington, D.C. (21). 1874. **C**

Williams, Charles H., M.D., 15 Arlington St., Boston, Mass. (22). 1874.

Williams, Geo. Huntington, Johns Hopkins Univ., Baltimore, Md. (33). 1886. **E**

Williams, Henry Shaler, Cornell Univ., Ithaca, N. Y. (18). 1882. **E F**

Williams, Prof. Henry W., 15 Arlington St., Boston, Mass. (11). 1874. **H F**

Williams, Prof. S. G., Cornell Univ., Ithaca, N. Y. (33). 1885. **E**

Wilson, Prof. Daniel, President University College, 117 Bloor St., Toronto, Canada (25). 1876. **H E**

Wilson, H. C., Cincinnati Observatory, Mt. Lookout, Hamilton Co., Ohio (30). 1885. **A**

Wilson, Joseph M., 435 Chestnut St., Philadelphia, Pa. (33). 1886. **D**

Winchell, Prof. Alex., Ann Arbor, Mich. (3). 1875. **E**

Winchell, Prof. N. H., Univ. of Minnesota, Minneapolis, Minn. (19). 1874. **E H**

Winlock, Wm. C., U. S. N. Observ., Washington, D. C. (33). 1885. **A B**

Woerd, Chas. V., Am. Watch Co., Waltham, Mass. (29). 1881. **D A**

Wood, Prof. De Volson, Hoboken, N. J. (29). 1881.

Woodbury, C. J. H., 31 Milk St., Boston, Mass. (29). 1884. **D**

Woodward, Prof. Calvin M., 1761 Missouri Ave., St. Louis, Mo. (32). 1884. **D A I**

Woodward, R. S., care of U. S. Geol. Survey, Washington, D. C. (33). 1885. **A B D**

Wormley, T. G., Univ. of Pennsylvania, Philadelphia, Pa. (20). 1878.

Worthen, A. H., Springfield, Ill. (5). 1874. **E**

Wright, Prof. Albert A., Oberlin College, Oberlin, Ohio (24). 1880. **E F**

Wright, Prof. Arthur W., Yale Coll., New Haven, Conn. (14). 1874. **A B**

Wright, Rev. Geo. F., Oberlin College, Oberlin, Ohio (29). 1882. **E**

Würtele, Rev. Louis C., Acton Vale, Province of Quebec, Can. (11). 1875. **E**

Wyckoff, Wm. C., 44 Howard St., New York, N. Y. (20). 1874.

Wylie, Prof. Theoph. A., Indiana Univ., Bloomington, Ind. (20). 1874.

Youmans, Prof. Edward L., New York, N. Y. (6). 1874.

Young, A. V. E., Northwestern Univ., Evanston, Ill. (33). 1886. **C B**

Young, C. A., Prof. of Astronomy, College of New Jersey, Princeton, N. J. (18). 1874. **A B D**

Zentmayer, Joseph, 147 S. Fourth St., Philadelphia, Pa. (29). 1882. **F**

[631 FELLOWS.]

Dec. 31, 1886. TOTAL NUMBER OF MEMBERS OF THE ASSOCIATION, 1886.

DECEASED MEMBERS.

[Information respecting omissions in this list, and the date of birth and of decease of any of the former members, is requested by the Permanent Secretary.]

Abbe, George W., New York, N. Y. (23). Died Sept. 25, 1879.

Abert, J. J., Washington, D. C. (1). Born in 1785. Died January 27, 1863.

Adams, C. B., Amherst, Mass. (1). Born January 11, 1814. Died Jan'y 19, 1853.

Adams, Edwin F., Charlestown, Mass. (18).

Adams, Samuel, Jacksonville, Ill. (18). Born Dec. 19, 1806. Died April 29, 1877.

Agassiz, Louis, Cambridge, Mass. (1). Born May 28, 1807. Died Dec. 14, 1873.

Ainsworth, J. G., Barry, Mass. (14).

Alexander, Stephen, Princeton, N. J. (1). Born Sept. 1, 1806. Died June 25, 1883.

Allen, Thomas, St. Louis, Mo. (27). Died April 8, 1882.

Allen, Zachariah, Providence, R. I. (1). Died March 17, 1882.

Allston, R. F. W., Georgetown, S. C. (8). Born April 21, 1801. Died April 7, 1864..

Alvord, Benjamin, Washington, D. C. (17). Died Oct. 16, 1884, at the age of 71.

Ames, M. P., Springfield, Mass. (1). Born in 1803. Died April 23, 1847.

Andrews, Ebenezer B., Lancaster, Ohio (7). Died Aug. 21, 1880, aged 59.

Anthony, Charles H., Albany, N. Y. (6). Died in 1874.

Appleton, Nathan, Boston, Mass. (1). Born Oct. 6, 1779. Died July 14, 1861.

Armstrong, John W., Fredonia, N. Y. (24).

Atwater, Mrs. S. T., Chicago, Ill. (17). Born Aug. 8, 1812. Died April 11, 1878.

Aufrecht, Louis, Cincinnati, Ohio (30).

Bache, Alexander D., Washington, D. C. (1). Born July 19, 1806. Died Feb. 17, 1867.

Bache, Franklin, Philadelphia, Pa. (1). Born Oct. 25, 1792. Died March 19, 1864.

Bailey, Jacob W., West Point, N. Y. (1). Born April 29, 1811. Died Feb. 26, 1857.

Bardwell, F. W., Lawrence, Kan. (13). Died in 1878.

Barnard, John G., New York, N. Y. (14). Died May 14, 1882.

Barrett, Moses, Milwaukee, Wis. (21). Died in 1873.

Barry, Redmond, Melbourne, Australia (25).
Bassnett, Thomas, Jacksonville, Fla. (8). Died Feb. 16, 1886, aged 79 years.
Beck, C. F., Philadelphia, Pa. (1).
Beck, Lewis C., New Brunswick, N. J. (1). Born Oct. 4, 1798. Died April 21, 1853.
Beck, T. Romeyn, Albany, N. Y. (1). Born Aug. 11, 1791. Died Nov. 19, 1855.
Beckwith, Henry C., Coleman's Station, N. Y. (29). Died July 12, 1885.
Belfrage, G. W., Clifton, Texas (29). Died Dec. 7, 1882.
Belt, Thomas, London, Eng. (27). Died Sept. 8, 1878.
Benedict, George W., Burlington, Vt. (16). Born Jan. 11, 1796. Died in 1871.
Bicknell, Edwin, Boston, Mass. (18). Born in 1830. Died March 19, 1877.
Binney, Amos, Boston, Mass. (1). Born Oct. 18, 1803. Died Feb. 1, 1847.
Binney, John, Boston, Mass. (3).
Blackie, Geo. S., Nashville, Tenn. (26).
Blair, Henry W., Washington, D. C., (26). Died Dec. 15, 1884.
Blake, Eli Whitney, New Haven, Conn. (1). Died Aug. 18, 1886, aged 91 years.
Blake, Homer C., New York, N. Y. (28). Born Feb. 1, 1822.
Blanding, William, ——, R. I. (1).
Blatchford, Thomas W., Troy, N. Y. (6).
Blatchley, Miss S. L., New Haven, Conn. (19). Died March 13, 1873.
Boadle, John, Haddonfield, N. J. (20). Born in 1805. Died in July, 1878.
Bomford, George, Washington, D. C. (1). Born 1780. Died March 25, 1848.
Bowron, James, South Pittsburg, Tenn. (26). Died in Dec., 1877.
Bradley, Leverette, Jersey City, N. J. (15). Died in 1875.
Braithwaite, Jos., Chambly, C. W. (11).
Briggs, Albert D., Springfield, Mass. (13). Died Feb. 20, 1881.
Briggs, Robert, Philadelphia, Pa. (29). Born May 18, 1822. Died July 24, 1882.
Brigham, Charles H., Ann Arbor, Mich. (17). Born July 27, 1820. Died in Jan., 1879.
Brown, Andrew, Natchez, Miss. (1).
Brown, Horace, Salem, Mass. (27). Died in July, 1883.
Bull, John, Washington, D. C. (31). Born Aug. 1, 1819. Died June 9, 1884.
Burbank, L. S., Woburn, Mass. (18).
Burke, Joseph Chester, Middletown, Conn. (29). Died in 1885.
Burnap, G. W., Baltimore, Md. (12). Born Nov. 30, 1802. Died Sept. 8, 1859.
Burnett, Waldo I., Boston, Mass. (1). Died July 1, 1854, aged 27.
Butler, Thomas B., Norwalk, Conn. (10). Born Aug. 22, 1806. Died June 8, 1873.

Cairns, F. A., New York, N. Y. (27). Died in 1879.
Campbell, Mrs. Mary H., Crawfordsville, Ind. (22). Died Feb. 27, 1882.
Carpenter, Thornton, Camden, S. C. (7).
Carpenter, William M., New Orleans, La. (1).
Case, Leonard, Cleveland, Ohio (15). Born June 27, 1820. Died Jan. 5, 1880.
Case, William, Cleveland, Ohio (6).
Caswell, Alexis, Providence, R. I. (2). Born Jan. 29, 1799. Died Jan. 8, 1877.
Chadbourne, Paul Ansel, Amherst, Mass. (10). Born Oct. 21, 1823. Died Feb. 23, 1883.
Chapman, N., Philadelphia, Pa. (1). Born May 28, 1780. Died July 1, 1853.
Chase, Stephen, Hanover, N. H. (2). Born in 1818. Died Aug. 5, 1851.
Chauvenet, William, St. Louis, Mo. (1). Born May 24, 1819. Died Dec. 13, 1870.
Cheesman, Louis M., Hartford, Conn. (32). Died in Jan. 1885, aged 27 yrs.
Cheney, Miss Margaret S., Jamaica Plain, Mass. (29). Died in 1882.
Clapp, Asahel, New Albany, Ind. (1). Born Oct. 5, 1792. Died Dec. 15, 1862.
Clark, Henry James, Cambridge, Mass. (18). Died July 1, 1873, aged 47.
Clark, Joseph, Cincinnati, Ohio (5).
Clarke, A. B., Holyoke, Mass. (13).
Cleaveland, C. H., Cincinnati, Ohio (9).
Cleveland, A. B., Cambridge, Mass. (2).
Coffin, James H., Easton, Pa. (1). Born Sept. 6, 1806. Died Feb. 6, 1873.
Cole, Thomas, Salem, Mass. (1). Born Dec. 24, 1779. Died June 24, 1852.
Coleman, Henry, Boston, Mass. (1).
Collins, Frederick, Washington, D. C. (28). Born Dec. 5, 1842. Died Oct. 27, 1881.
Conrad, Timothy Abbott, Philadelphia, Pa. (1). Born in August, 1803. Died August 9, 1877.
Cooke, Caleb, Salem, Mass. (18). Born Feb. 15, 1838. Died June 5, 1880.
Cooper, William, Hoboken, N. J. (9). Died in 1864.
Copes, Joseph S., New Orleans, La. (11). Born Dec. 9, 1811. Died March 1, 1885.
Corning, Erastus, Albany, N. Y. (6). Born Dec. 14, 1794. Died April 9, 1872.
Costin, M. P., Fordham, N. Y. (30). Died June 8, 1884.
Couper, James Hamilton, Darien, Ga. (1). Born March 5, 1794. Died July 3, 1866.
Cramp, J. M., Wolfville, N. S. (11). Born July 25, 1796. Died Dec. 6, 1881.
Crehore, John D., Cleveland, Ohio (24).
Crocker, Charles F., Lawrence, Mass. (22). Died in July, 1881.
Crocker, Miss Lucretia, Boston, Mass. (29). Died in 1886.
Crosby, Alpheus, Salem, Mass. (10). Born Oct. 13, 1810. Died April 17, 1874.

Crosby, Thomas R., Hanover, N. H. (18). Born Oct. 22, 1816. Died March 1, 1872.

Croswell, Edwin, Albany, N. Y. (6). Born in May, 1797. Died June 13, 1871.

Crow, Wayman, St. Louis, Mo. (27). Born March 7, 1808. Died May 10, 1885.

Curry, W. F., Geneva, N. Y. (11).

Curtis, Josiah, Washington, D. C. (18). Died Aug. 1, 1883.

Dalrymple, E. A., Baltimore, Md. (11). Died Oct. 30, 1881.

Dayton, Edwin A., Madrid, N. Y. (7). Born in 1827. Died June 24, 1873.

Dean, Amos, Albany, N. Y. (6). Born Jan. 16, 1803. Died Jan. 26, 1868.

Dearborn, George H. A. S., Roxbury, Mass. (1).

Dekay, James E., New York, N. Y. (1). Born in 1792. Died Nov. 21, 1851.

DeLaski, John, Carver's Harbor, Me. (18).

Devereux, J. H., Cleveland, Ohio (18). Died March 17, 1886.

Dewey, Chester, Rochester, N. Y. (1). Born Oct. 25, 1781. Died Dec. 15, 1867.

Dexter, G. M., Boston, Mass. (11).

Dillingham, W. A. P., Augusta, Me. (17).

Dimmick, L. N., Santa Barbara, Cal. (29). Died May 31, 1884.

Dixwell, Geo. B., Boston, Mass. (29). Died April, 1885.

Doggett, Mrs. Kate N., Chicago, Ill. (17). Died March 12, 1884.

Doggett, Wm. E., Chicago, Ill. (17). Born Nov. 20, 1820. Died in 1876.

Doolittle, L., Lenoxville, C. E. (11). Died in 1862.

Dorr, E. P., Buffalo, N. Y. (15). Died March 28, 1881.

Draper, Henry, New York, N. Y. (28).

Ducatel, J. T., Baltimore, Md. (1).

Duffield, George, Detroit, Mich. (10). Born July 4, 1794. Died June 26, 1869.

Dumont, A. H., Newport, R. I. (14).

Duncan, Lucius C., New Orleans, La. (10). Died Aug. 9, 1855, aged 54.

Dunn, R. P., Providence, R. I. (14).

Easton, Norman, Fall River, Mass. (14). Died Dec. 21, 1872.

Eaton, James H., Beloit, Wis. (17). Died Jan. 5, 1877.

Elsberg, Louis, New York, N. Y. (23). Died Feb. 19, 1885, aged 48 years.

Elwyn, Alfred L., Philadelphia, Pa. (1). Died March 15, 1884.

Ely, Charles Arthur, Elyria, Ohio (4).

Emerson, Geo. B., Boston, Mass. (1). Born Sept. 12, 1797. Died March 4, 1881.

Emmons, Ebenezer, Williamstown, Mass. (1). Born May 16, 1799. Died October 1, 1863.

Engelmann, George, St. Louis, Mo. (1). Born Feb. 2, 1809. Died Feb. 4, 1884.

Engstrom, A. B., Burlington, N. J. (1).

Eustis, Henry L., Cambridge, Mass. (2). Born Feb. 1, 1819. Died Jan. 11, 1885.

Everett, Edward, Boston, Mass. (2). Born April 11, 1794. Died Jan. 15, 1865.

Ewing, Thomas, Lancaster, Ohio (5). Born Dec. 28, 1789. Died Oct. 26, 1871.

Faries, R. J., Wauwatosa, Wis. (21). Died May 31, 1878.

Farquharson, Robert James, Des Moines, Iowa (24). Born July 15, 1824. Died Sept. 6, 1884.

Ferris, Isaac, New York, N. Y. (6). Born Oct. 9, 1798. Died June 16, 1873.

Feuchtwanger, Lewis, New York, N. Y. (11). Died June 25, 1876.

Fillmore, Millard, Buffalo, N. Y. (7). Born Jan. 7, 1800. Died March 8, 1874.

Fisher, Mark, Trenton, N. J. (10).

Fitch, Alexander, Hartford, Conn. (1). Born March 25, 1799. Died Jan. 20, 1859.

Fitch, O. H., Ashtabula, Ohio (7). Died Sept. 17, 1882, in his 80th year.

Forbush, E. B., Buffalo, N. Y. (15).

Force, Peter, Washington, D. C. (4). Born Nov. 26, 1790. Died Jan. 23, 1868.

Ford, A. C., Nashville, Tenn. (26).

Forshey, Caleb G., New Orleans, La. (21). Died in Aug., 1881.

Foster, John W., Chicago, Ill. (1). Born March 4, 1815. Died June 29, 1873.

Foucon, Felix, Madison, Wis. (18).

Fowle, Wm. B., Boston, Mass. (1). Born Oct. 17, 1795. Died Feb. 6, 1865.

Fox, Charles, Grosse Ile, Mich. (7).

Frazer, John F., Philadelphia, Pa. (1). Born July 8, 1812. Died Oct. 12, 1872.

Freeman, Spencer Hedden, Cleveland, Ohio (29). Born Oct. 3, 1855. Died Feb. 2, 1886.

French, J. W., West Point, N. Y. (11).

Garber, A. P., Columbia, Pa. (29). Died Aug. 26, 1881.

Gavit, John E., New York, N. Y. (1).

Gay, Martin, Boston, Mass. (1). Died Jan. 12, 1850, aged 46.

Gibbon, J. H., Charlotte, N. C. (3).

Gillespie, W. M., Schenectady, N. Y. (10). Born in 1816. Died Jan'y 1, 1868.

Gilmor, Robert, Baltimore, Md. (1).

Glazier, W. W., Key West, Fla. (29). Died Dec. 11, 1880.

Goldmark, J., New York, N. Y. (29). Died in April, 1882.

Gould, Augustus A., Boston, Mass. (11). Born April 23, 1805. Died Sept. 15, 1866.

Gould, B. A., Boston, Mass. (2). Born June 15, 1787. Died Oct. 24, 1859.
Graham, James D., Washington, D. C. (1). Born in 1799. Died Dec. 28, 1865.
Gray, Alonzo, Brooklyn, N. Y. (13). Born in 1808. Died March 10, 1860.
Gray, James H., Springfield, Mass. (6).
Greene, Benjamin D., Boston, Mass. (1). Died Oct. 14, 1862, aged 68.
Greene, Everett W., Madison, N. J. (10). Died in 1864.
Greene, Samuel, Woonsocket, R. I. (9). Died in 1868.
Greer, James, Dayton, Ohio (20). Died in Feb., 1874.
Griffith, Robert E., Philadelphia, Pa. (1).
Griswold, John A., Troy, N. Y. (19). Born in 1822. Died Oct. 31, 1872.
Guest, William E., Ogdensburg, N. Y. (6).
Guyot, Arnold, Princeton, N. J. (1). Born Sept. 5, 1809. Died Feb. 8, 1884.

Hackley, Charles W., New York, N. Y. (4). Born March 9, 1809. Died January 10, 1861.
Hadley, George, Buffalo, N. Y. (6). Born June, 1813. Died Oct. 16, 1877.
Haldeman, S. S., Chickies, Pa. (1). Died Sept. 10, 1880, aged 68.
Hale, Enoch, Boston, Mass. (1). Born Jan. 29, 1790. Died Nov. 12, 1848.
Hance, Ebenezer, Fallsington P. O., Pa. (7). Died in 1876.
Harding, Myron H., Lawrenceburg, Ind. (30.) Died Sept., 1885.
Hare, Robert, Philadelphia, Pa. (1). Born Jan. 17, 1781. Died May 15, 1858.
Harlan, Joseph G., Haverford, Pa. (8).
Harlan, Richard, Philadelphia, Pa. (1).
Harris, Thaddeus W., Cambridge, Mass. (1). Born Nov. 12, 1795. Died Jan. 16, 1856.
Harrison, A. M., Plymouth, Mass. (29).
Harrison, Jos., jr., Philadelphia, Pa. (12).
Hart, Simeon, Farmington, Conn. (1). Died April 20, 1853, aged 57.
Hartt, Charles F., Ithaca, N. Y. (18). Born in 1840. Died March 18, 1878.
Haven, Joseph, Chicago, Ill. (17). Born Jan. 4, 1816. Died May 23, 1874.
Hawes, George W., Washington, D. C. (23). Born Dec. 31, 1848. Died June 22, 1882.
Hayden, Horace H., Baltimore, Md. (1). Born Oct. 13, 1768.
Hayes, George E., Buffalo, N. Y. (15).
Hayward, James, Boston, Mass. (1). Died July 27, 1866, aged 80.
Hedrick, Benjamin Sherwood, Washington, D. C. (19). Died Sept. 2, 1886, aged 60.
Hempstead, G. S. B., Portsmouth, Ohio (29). Died July 9, 1883, in his 89th year.
Henry, Joseph, Washington, D. C. (1). Born Dec. 17, 1797. Died May 13, 1878.
Hickox, S. V. R., Chicago, Ill. (17). Died in 1872.
Hicks, William C., New York, N. Y. (34). Died in 1885.
Hilgard, Theo. C., St. Louis, Mo. (17). Born Feb. 28, 1828. Died Mch. 5, 1875.

Hill, Walter N., Chester, Pa. (29). Born April 15, 1846. Died March 29, 1884.

Hincks, William, Toronto, C. W. (11).

Hitchcock, Edward, Amherst, Mass. (1). Born May 24, 1793. Died Feb. 27, 1864.

Hoadley, John Chipman, Boston, Mass. (29). Born Dec. 10, 1818. Died Oct. 21, 1886.

Hodgson, W. B., Savannah, Ga. (10). Born 1815.

Holbrook, John E., Charleston, S. C. (1). Born Dec. 31, 1796. Died Sept. 8, 1871.

Holman, Mrs. S. W., Boston, Mass. (29). Died May 5, 1885.

Hopkins, Albert, Williamstown, Mass. (19). Born July 14, 1807. Died May 25, 1872.

Hopkins, James G., Ogdensburg, N. Y. (10). Died in 1860.

Hopkins, T. O., Williamsville, N. Y. (10). Died in 1866.

Hopkins, Wm., Lima, N. Y. (5.) Died in March, 1867.

Hoppock, A. E., Hastings-on-Hudson, N. Y. (29).

Horton, C. V. R., Chaumont, N. Y. (10). Died in 1862.

Horton, William, Craigville, N. Y. (1).

Hosford, Benj. F., Haverhill, Mass. (13). Died in 1864.

Hough, Franklin B., Lowville, N. Y. (4). Born 1822. Died June 11, 1885.

Houghton, Douglas, Detroit, Mich. (1). Born Sept. 21, 1809. Died Oct. 13, 1845.

Hovey, Edmund O., Crawfordsville, Ind. (20). Born July 15, 1801. Died March 10, 1877.

Howland, Theodore, Buffalo, N. Y. (15).

Hubbert, James, Richmond, Province of Quebec (16). Died in 1868.

Hunt, Edward B., Washington, D. C. (2). Born June 15, 1822. Died Oct. 2, 1863.

Hunt, Freeman, New York, N. Y. (11). Born March 21, 1804. Died March 2, 1858.

Ives, Moses B., Providence, R. I. (9). Died in 1857.

Ives, Thomas P., Providence, R. I. (10).

Jackson, Charles T., Boston, Mass. (1). Born June 21, 1805. Died Aug. 29, 1880.

James, Thomas Potts, Cambridge, Mass. (22). Born Sept. 1, 1803. Died Feb. 22, 1882.

Johnson, Walter R., Washington, D. C. (1). Born June 21, 1794. Died April 26, 1852.

Johnson, William Schuyler, Washington, D. C. (31). Born Sept. 20, 1859. Died Oct. 6, 1883.

Jones, Catesby A. R., Washington, D. C. (8).

Jones, Henry A., Portland, Me. (29). Died Sept. 3, 1883.

Jones, James H., Boston, Mass. (28).

Kedzie, W. K., Oberlin, Ohio (25).

Keely, George W., Waterville, Me. (1). Died in 1878.

Keep, N. C., Boston, Mass. (18). Died in March, 1875.

Kennicott, Robert, West Northfield, Ill. (12). Born Nov. 13, 1835. Died in 1866.

Kerr, Washington Caruthers, Raleigh, N. C. (10). Died Aug. 9, 1885, aged 56 years.

Kidder, Henry Purkitt, Boston, Mass. (29). Born Jan. 8, 1823. Died Jan. 28, 1886.

King, Mitchell, Charleston, S. C. (3). Born June 8, 1783. Died in 1862.

Kite, Thomas, Cincinnati, Ohio (5). Died Feb. 6, 1884.

Klippart, John H., Columbus, Ohio (17). Died October, 1878.

Knickerbocker, Charles, Chicago, Ill. (17). Died in 1873.

Knight, J. B., Philadelphia, Pa. (21). Died March 10, 1879.

Lacklan, R., Cincinnati, Ohio (11).

Lapham, Increase A., Milwaukee, Wis. (3). Born March 7, 1811. Died Sept. 14, 1875.

LaRoche, R., Philadelphia, Pa. (12).

Lasel, Edward, Williamstown, Mass. (1). Born Jan. 21, 1809. Died in 1852.

Lawford, Frederick, Montreal, Canada (11). Died in 1866.

Lawrence, Edward, Charlestown, Mass. (18). Born June, 1810. Died Oct. 17, 1885.

Lea, Isaac, Philadelphia, Pa. (1). Born March 4, 1792. Died Dec. 8, 1886.

Le Conte, John Lawrence, Philadelphia, Pa. (1). Born May 13, 1825. Died Nov. 15, 1883.

Lederer, Baron von, Washington, D. C. (1).

Lieber, Oscar M., Columbia, S. C. (8). Born Sept. 8, 1830. Died June 27, 1862.

Lincklaen, Ledyard, Cazenovia, N. Y. (1). Died April 25, 1864.

Linsley, James H., Stafford, Conn. (1). Born May 5, 1787. Died Dec. 26, 1843.

Lockwood, Moses B., Providence, R. I. (9). Died in 1872.

Logan, William E., Montreal, Canada (1). Born April 23, 1798. Died June 22, 1875.

Loiseau, Emile F., Brussels, Belgium (33). Died April 30, 1886.

Loosey, Charles F., New York, N. Y. (12).

Lothrop, Joshua R., Buffalo, N. Y. (15).

Lowrie, J. R., Warriorsmark, Pa. (29). Died Dec. 10, 1885.

Lyon, Sidney S., Jeffersonville, Ind. (20). Born Aug. 4, 1808. Died June 24, 1872.

M'Conihe, Isaac, Troy, N. Y. (5).

McFadden, Thomas, Westerville, Ohio (30). Born Nov. 9, 1825. Died Nov. 9, 1883.

McMahon, Mathew, Albany, N. Y. (11).

Maack, G. A., Cambridge, Mass. (18). Died in Aug., 1873.

Macfarlane, James, Towanda, Pa. (29). Died in 1885.

Mahan, Dennis H., West Point, N. Y. (9). Born April 2, 1802. Died Sept. 16, 1871.
Marsh, Dexter, Greenfield, Mass. (1).
Marsh, James E., Roxbury, Mass. (10).
Martin, B. N., New York, N. Y. (23). Died Dec. 26, 1883.
Mather, William W., Columbus, Ohio (1). Born May 24, 1804. Died Feb. 27, 1859.
Maude, John B., St. Louis, Mo. (27). Died in April, 1879.
Maupin, S., Charlottesville, Va. (10).
Meade, George G., Philadelphia, Pa. (15). Born Dec. 30, 1815. Died Nov. 6, 1872.
Meek, F. B., Washington, D. C. (6). Born December 10, 1817. Died December 21, 1876.
Meigs, James Aitken, Philadelphia, Pa. (12). Born July 30, 1829. Died Nov. 9, 1879.
Minifie, William, Baltimore, Md. (12). Born in 1805. Died Oct. 24, 1880.
Mitchel, O. M., Cincinnati, Ohio (3). Born Aug. 28, 1810. Died Oct. 30, 1862.
Mitchell, William, Poughkeepsie, N. Y. (2). Died April 2, 1869, aged 76.
Mitchell, Wm. H., Florence, Ala. (17).
Morgan, Lewis H., Rochester, N. Y. (10). Born Nov. 21, 1818. Died Dec. 17, 1881.
Morgan, Mrs. Mary E., Rochester, N. Y. (31). Died in 1884.
Morris, John B., Nashville, Tenn. (26).
Morton, Samuel G., Philadelphia, Pa. (1). Born Jan. 26, 1799. Died May 15, 1851.
Monroe, Nathan, Bradford, Mass. (6). Born May 16, 1804. Died July 8, 1866.
Monroe, William, Concord, Mass. (18). Died April 27, 1877.
Mudge, Benjamin F., Manhattan, Kansas (25). Born Aug. 11, 1817. Died Nov. 21, 1879, aged 62.
Muir, William, Montreal, Can. (31). Died July, 1885.
Mussey, William H., Cincinnati, Ohio (30). Born Sept. 13, 1818. Died Aug. 1, 1882.

Newland, John, Saratoga Springs, N. Y. (28). Died Jan. 18, 1880.
Newton, E. H., Cambridge, N. Y. (1).
Nichols, Charles A., Providence, R. I. (17). Born Jan. 4, 1826. Died Oct. 20, 1877.
Nichols, William Ripley, Boston, Mass. (18). Died July 14, 1886, aged 39.
Nicholson, Thomas, New Orleans, La. (21).
Nicollett, Jean N., Washington, D. C. (1). Born July 24, 1786. Died Sept. 11, 1843.
Norton, John P., New Haven, Conn. (1). Born in July, 1822. Died Sept. 5, 1852.
Norton, W. A., New Haven, Conn. (6).
Noyes, J. O., New Orleans, La. (21).
Nutt, Cyrus, Bloomington, Ind. (20). Died in 1875.

Oakes, Wm., Ipswich, Mass. (1). Born July 1, 1799. Died July 31, 1848.

Ogden, Robert W., New Orleans, La. (21). Died March 24, 1878.

Ogden, William B., High Bridge, Westchester Co., N. Y. (17). Born in 1805. Died Aug. 3, 1877.

Olmsted, Alexander F., New Haven, Conn. (4). Born Dec. 20, 1822. Died May 5, 1853.

Olmsted, Denison, New Haven, Conn. (1). Born June 18, 1791. Died May 13, 1859.

Olmsted, Denison, jr., New Haven, Conn. (1). Born Feb. 16, 1824. Died Aug. 15, 1846.

Orton, James, Poughkeepsie, N. Y. (18). Died Sept. 24, 1877.

Osbun, Isaac J., Salem, Mass. (29).

Otis, George Alexander, Washington, D. C. (10). Born Nov. 12, 1830. Died Feb. 23, 1881.

Packer, Harry E., Mauch Chunk, Pa. (30). Died Feb. 1, 1884.

Painter, Jacob, Lima, Pa. (23). Died in 1876.

Painter, Minshall, Lima, Pa. (7).

Parker, Wilbur F., West Meriden, Conn. (23). Died in 1876.

Parkman, Samuel, Boston, Mass. (1). Died Dec. 15, 1854, aged 38.

Parsons, Henry B., New York, N. Y. (30). Born in 1855. Died Aug. 21, 1885.

Payn, Charles H., Saratoga Springs, N. Y. (28). Born May 16, 1814. Died Dec. 20, 1881.

Peirce, B. O., Beverly, Mass. (18). Died Nov. 12, 1883, aged 71 years.

Peirce, Benjamin, Cambridge, Mass. (1). Born April 4, 1809. Died Oct. 6, 1880.

Perkins, George R., Utica, N. Y. (1). Born May 3, 1812. Died Aug. 22, 1876.

Perkins, Henry C., Newburyport, Mass. (18). Born Nov. 13, 1804. Died Feb. 2, 1873.

Perry, John B., Cambridge, Mass. (16). Died Oct. 3, 1872, aged 52.

Perry, M. C., New York, N. Y. (10).

Phelps, Mrs. Almira Hart Lincoln, Baltimore, Md. (13). Died July 15, 1884, in her 91st year.

Phillips, John C., Boston, Mass. (29). Died March 1, 1885, aged 46 yrs. 9 mos.

Piggot, A. Snowden, Baltimore, Md. (10).

Pim, Bedford Clapperton Trevelyan, London, Eng. (33). Died Oct., 1886, aged 60 years.

Platt, W. G., Philadelphia, Pa. (32). Died Nov., 1885.

Plumb, Ovid, Salisbury, Conn. (9).

Pope, Charles A., St. Louis, Mo. (12). Born May 15, 1818. Died July 6, 1870.

Porter, John A., New Haven, Conn. (14). Born March 15, 1822. Died Aug. 25, 1866.

Potter, Stephen H., Hamilton, Ohio (30). Born Nov. 10, 1812. Died Dec. 9, 1883.
Pourtalès, Louis François de, Cambridge, Mass. (1). Born in 1822. Died July 18, 1880.
Pruyn, John V. L., Albany, N. Y. (1). Born June 22, 1811. Died Nov. 21, 1877.
Pugh, Evan, Centre Co., Pa. (14).
Pulsifer, Sidney, Philadelphia, Pa. (21). Died March 24, 1884.
Putnam, Mrs. F. W., Cambridge, Mass. (19). Born Dec. 29, 1838. Died March 10, 1879.
Putnam, J. Duncan, Davenport, Iowa (27). Born Oct. 18, 1855. Died Dec. 10, 1881.

Read, Ezra, Terre Haute, Ind. (20). Died in 1877.
Redfield, William C., New York, N. Y. (1). Born March 26, 1789. Died Feb. 12, 1857.
Resor, Jacob, Cincinnati, Ohio (8). Died in 1871.
Robb, James, Fredericton, N. B. (4).
Robinson, Coleman T., Buffalo, N. Y. (15).
Rockwell, John A., Norwich, Conn. (10). Born August 27, 1803. Died February 10, 1861.
Rogers, Henry D., Glasgow, Scotland (1). Born 1809. Died May 29, 1866.
Rogers, James B., Philadelphia, Pa. (1). Born February 22, 1803. Died June 15, 1852.
Rogers, Robert E., Philadelphia, Pa. (18). Died Sept. 7, 1884.
Rogers, William Barton, Boston, Mass. (1). Born Dec. 7, 1804. Died May 30, 1882.
Root, Elihu, Amherst, Mass. (25). Born Sept. 14, 1845.

Sager, Abram, Ann Arbor, Mich. (6). Born December 22, 1810. Died August 6, 1877.
Sanders, Benjamin D., Wellsburg, W. Va. (19).
Schaeffer, Geo. C., Washington, D. C. (1). Died in 1873.
Schley, William, New York, N. Y. (28). Died in 1882.
Scott, Joseph, Dunham, C. E. (11). Died in 1865.
Seaman, Ezra C., Ann Arbor, Mich. (20). Born Oct. 14, 1805. Died in his 74th year.
Senter, Harvey S., Aledo, Ill. (20). Died in 1875.
Seward, William H., Auburn, N. Y. (1). Born May 16, 1801. Died Oct. 10, 1872.
Sheppard, William, Drummondville, Province of Quebec, Can. (11). Born in 1783. Died in 1867.
Sherwin, Thomas, Dedham, Mass. (11). Born March 26, 1799. Died July 23, 1869.
Silliman, Benjamin, New Haven, Conn. (1). Born August 8, 1779. Died November 22, 1864.

Silliman, Benjamin, New Haven, Conn. (1). Born Dec. 4, 1816. D Jan. 14, 1885.

Skinner, John B., Buffalo, N. Y. (15). Died in 1871.

Slack, J. H., Philadelphia, Pa. (12).

Smith, Charles A., St. Louis, Mo. (27). Died in 1884.

Smith, David P., Springfield, Mass. (29). Born Oct. 1, 1830. Died I 26, 1880.

Smith, Mrs. Erminnie A., Jersey City, N. J. (25). Died June 9, 18 aged 48.

Smith, J. Lawrence, Louisville, Ky. (1). Born Dec. 16, 1818. Died (12, 1883.

Smith, J. V., Cincinnati, Ohio (5).

Smith, James Y., Providence, R. I. (9). Born September 15, 1809. I in 1876.

Smith, Lyndon A., Newark, N. J. (9). Born November 11, 1795. D December 15, 1865.

Snell, Ebenezer S., Amherst, Mass. (2). Born October 7, 1801. Die September, 1877.

Sparks, Jared, Cambridge, Mass. (2). Born May 10, 1819. Died Ma 14, 1866.

Spinzig, Charles, St. Louis, Mo. (27). Died Jan. 22, 1882.

Stearns, Josiah A., Boston, Mass. (29).

Stimpson, William, Chicago, Ill. (12). Died May 26, 1872.

Stone, Samuel, Chicago, Ill. (17). Born Dec. 6, 1798. Died May 4, 18

St. John, Joseph S., Albany, N. Y. (28). Died Nov. 23, 1882.

Sullivant, William S., Columbus, Ohio (7). Born Jan 15, 1803. D April 30, 1873.

Sutton, George, Aurora, Ind. (20.) Died June 13, 1886.

Swain, James, Fort Dodge, Iowa (21). Born in 1816. Died in 1877.

Tallmadge, James, New York, N. Y. (1). Born Jan. 20, 1778. Died C 3, 1853.

Taylor, Arthur F., Cleveland, Ohio (29). Born Dec. 10, 1853. D June 28, 1883.

Taylor, Richard C., Philadelphia, Pa. (1). Born January 18, 1789. I November 26, 1851.

Tenney, Sanborn, Williamstown, Mass. (17). Born in January, 1827. D July 11, 1877.

Teschemacher, J. E., Boston, Mass. (1). Died Nov. 9, 1853, aged 63.

Thompson, A. Remsen, New York, N. Y. (1). Died in Oct., 1879.

Thompson, Alexander, Aurora, N. Y. (1).

Thompson, Charles O., Terre Haute, Ind. (29). Died in 1885.

Thompson, Zadock, Burlington, Vt. (1). Born May 23, 1796. Died J 19, 1856.

Thomson, Henry R., Crawfordsville, Ind. (30). Died in 1884.

Thurber, Isaac, Providence, R. I. (9).

Tillman, Samuel D., Jersey City, N. J. (15). Died in 1875.

Tobin, Thomas W., Louisville, Ky. (30). Died Aug. 4, 1883.
Todd, Albert, St. Louis, Mo. (27). Died April, 1885, aged 72 years.
Tolderoy, James B., Fredericton, N. B. (11).
Torrey, John, New York, N. Y. (1). Born Aug. 15, 1796. Died March 10, 1873.
Torrey, Joseph, Burlington, Vt. (2). Born Feb. 2, 1797. Died Nov. 26, 1867.
Totten, Joseph G., Washington, D. C. (1). Born August 23, 1788. Died April 22, 1864.
Townsend, Howard, Albany, N. Y. (10). Died in 1867.
Townsend, John K., Philadelphia, Pa. (1).
Townsend, Robert, Albany, N. Y. (9). Died in 1866.
Troost, Gerard, Nashville, Tenn. (1). Born March 15, 1776. Died Aug. 14, 1850.
Tuomey, Michael, Tuscaloosa, Ala. (1). Born September 29, 1805. Died March 20, 1857.
Tyler, Edward R., New Haven, Conn. (1). Died Sept. 28, 1848.

Vancleve, John W., Dayton, Ohio (1).
Vanuxem, Lardner, Bristol, Pa. (1).
Vaux, William S., Philadelphia, Pa. (1). Born May 19, 1811. Died May 5, 1882.

Wadsworth, James S., Genesee, N. Y. (2). Born October 30, 1807. Died May 8, 1864.
Wagner, Tobias, Philadelphia, Pa. (9).
Walker, Joseph, Oxford, N. Y. (10).
Walker, Sears C., Washington, D. C. (1). Born March 28, 1805. Died January 30, 1853.
Walker, Timothy, Cincinnati, Ohio (4). Born Dec. 1, 1802. Died Jan. 15, 1856.
Walsh, Benjamin D., Rock Island, Ill. (17).
Wanzer, Ira, Brookfield, Conn. (18). Born April 17, 1796. Died March 5, 1879.
Warren, Geo. Washington, Boston, Mass. (18). Died in 1884.
Warren, Gouverneur Kemble, Newport, R. I. (12). Died Aug. 8, 1882, in his 64th year.
Warren, John C., Boston, Mass. (1). Born Aug. 1, 1778. Died May 4, 1856.
Watertown, Charles, Wakefield, Eng. (1).
Watkins, Samuel, Nashville, Tenn. (26).
Watson, J. Craig, Ann Arbor, Mich. (13). Born Jan. 28, 1838. Died Nov. 23, 1880.
Webster, Horace B., Albany, N. Y. (1). Died Dec. 8, 1843.
Webster, M. H., Albany, N. Y. (1).
Webster, J. W., Cambridge, Mass. (1). Died Aug. 30, 1850, aged 57.
Weed, Monroe, Wyoming, N. Y. (6). Died in 1867.
Welch, Mrs. G. O., Lynn, Mass. (21). Died in June, 1882.

Welsh, John, Philadelphia, Pa. (33). Died May, 1886.

Weyman, George W., Pittsburgh, Pa. (6). Born April, 1832. Died J
16, 1864.

Wheatland, Richard H., Salem, Mass. (13). Born July 6, 1830. D
Dec. 21, 1863.

Wheatley, Charles M., Phœnixville, Pa. (1). Died May 6, 1882.

Wheeler, Arthur W., Baltimore, Md. (29). Born in March, 1859. D
Jan. 6, 1881.

White, Samuel S., Philadelphia, Pa. (23). Died Dec. 30, 1879.

Whiting, Lewis E., Saratoga Springs, N. Y. (28). Born March 7, 1
Died Aug. 2, 1882.

Whitman, Edmund B., Cambridge, Mass. (29). Died Sept. 2, 1883.

Whitman, Wm. E., Philadelphia, Pa. (23). Died in 1875.

Whitney, Asa, Philadelphia, Pa. (1). Born Dec. 1, 1791. Died June 4, 18

Whittlesey, Charles, Cleveland, Ohio (1). Born Oct. 5, 1808. Died O
18, 1886.

Whittlesey, Charles C., St. Louis, Mo. (11). Died in 1872.

Wilder, Graham, Louisville, Ky. (30). Born July 1, 1843. Died Jan.
1885.

Willard, Emma, Troy, N. Y. (15). Born Feb. 23, 1787. Died April
1870.

Williams, Frank, Buffalo, N. Y. (25). Died Aug. 13, 1884.

Williamson, R. S., San Francisco, Cal. (12).

Wilson, W. C., Carlisle, Pa. (12).

Winlock, Joseph, Cambridge, Mass. (5). Born Feb. 6, 1826. Died Ju
11, 1875.

Woodbury, Levi, Portsmouth, N. H. (1). Born Dec. 22, 1789. Died Se
4, 1851.

Woodman, John S., Hanover, N. H. (11). Born in 1819. Died May
1871.

Woodward, J. J., Washington, D. C. (28). Born Oct. 30, 1833. D
Aug. 17, 1884.

Wright, Elizur, Boston, Mass. (31). Born Feb. 12, 1804. Died Nov.
1885.

Wright, John, Troy, N. Y. (1).

Wyman, Jeffries, Cambridge, Mass. (1). Born Aug. 11, 1814. Died Se
4, 1874.

Yarnall, M., Washington, D. C. (26). Born in 1817. Died Jan. 27, 18

Young, Ira, Hanover, N. H. (1). Died Sept. 14, 1858, aged 57.

ADDRESS

BY

H. A. NEWTON,

THE RETIRING PRESIDENT OF THE ASSOCIATION.

MR. PRESIDENT, LADIES AND GENTLEMEN OF THE ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:—

YOU are kindly giving to me an hour to-night in which I may speak to you. I do not have enough confidence in myself to justify me in speaking to such an audience as this upon one of those broad subjects that belong equally to all sections of the Association. The progress, the encouragements and the difficulties in each field are best known to the workers in the field, and I should do you little good by trying to sum up and recount them. Let me rather err then, if at all, by going to the opposite extreme.

Two years ago your distinguished President instructed and delighted us all by speaking of the Pending Problems of Astronomy, what they are and what hopes we have of solving them. To one subject in this one science, a subject so subordinate that he very properly gave it only brief notice, I ask your attention. I propose to state some propositions which we may believe to be probably true about the meteorites, the meteors, and the shooting stars.

In trying to interest you in this subject so remote from your ordinary studies I rely upon your sense of the unity of all science, and at the same time upon the strong hold which these weird bodies have ever had upon the imaginations of men. In ancient times temples were built over the meteorite images that fell down from Jupiter and divine worship was paid them, and in these later days a meteorite stone that fell last year in India became the object of daily anointings and other ceremonial worship. In the fearful imagery of the Apocalypse the terrors are deepened by there falling "from heaven a great star burning as a torch," and by the stars of heaven falling "unto the earth as a fig tree cast-

eth her unripe figs when she is shaken of a great wind." The "great red dragon having seven heads and ten horns and upon his heads seven diadems" is presented in the form of a huge fire-ball. "His tail draweth the third part of the stars of heaven, and did cast them to the earth." Records of these feared visitors under the name of flying dragons are found all through the pages of the monkish chroniclers of the Middle Ages. The Chinese appointed officers to record the passage of meteors and comets for they were thought to have somewhat to say to the weal or woe of rulers and people.

By gaining in these later days a sure place in science, these bodies have lost their terrors, but so much of our knowledge about them is fragmentary, and there is still so much that is mysterious, that men have loved to speculate about their origin, their functions, and their relations to other bodies in the solar system. It has been easy, and quite common too, to make these bodies the cause of all kinds of things for which other causes could not be found.

They came from the moon; they came from the earth's volcanoes; they came from the sun; they came from Jupiter and the other planets; they came from some destroyed planet; they came from comets; they came from the nebulous mass from which the solar system has grown; they came from the fixed stars; they came from the depths of space.

They supply the sun with his radiant energy; they give the moon her accelerated motion; they break in pieces heavenly bodies; they threw up the mountains on the moon; they made large gifts to our geologic strata; they cause the auroras; they give regular and irregular changes to our weather.

A comparative geology has been built up from the relations of the earth's rocks to the meteorites; a large list of new animal forms has been named from their concretions; and the possible introduction of life to our planet has been credited to them.

They are satellites of the earth; they travel in streams, and in groups, and in isolated orbits about the sun; they travel in groups and singly, through stellar spaces; it is they that reflect the zodiacal light; they constitute the tails of comets; the solar corona is due to them; the long coronal rays are meteor streams seen edgewise.

Nearly all of these ideas have been urged by men deservedly of the highest repute for good, personal work in adding to human

knowledge. In presence of this host of speculations, it will not, I hope, be a useless waste of your time to inquire what we may reasonably believe to be probably true. And if I shall have no new hypothesis to give to you, I offer as my excuse that nearly all possible ones have been already put forth. This Association exists it is true, for the advancement of science, but science may be advanced by rejecting bad hypotheses as well as by forming good ones.

I begin with a few propositions about which there is now practical unanimity among men of science. Such propositions need only be stated. The numbers that are to be given express quantities that are open to revision and moderate changes.

1. The luminous meteor tracks are in the upper part of the earth's atmosphere. Few meteors, if any, appear at a height greater than one hundred miles, and few are seen below a height of thirty miles from the earth's surface, except in rare cases, when stones and irons fall to the ground. All these meteor tracks are caused by bodies which come into the air from without.

2. The velocities of the meteors in the air are comparable with that of the earth in its orbit about the sun. It is not easy to determine the exact values of those velocities, yet they may be roughly stated as from fifty to two hundred and fifty times the velocity of sound in the air, or of a cannon ball.

3. It is a necessary consequence of these velocities that the meteors move about the sun and not about the earth as the controlling body.

4. There are four comets related to four periodic star-showers that have occurred on the dates April 20th, August 10th, November 14th and November 27th. The meteoroids which have given us any one of these star-showers constitute a group, each individual of which moves in a path which is like that of the corresponding comet. The bodies are, however, now too far from one another to influence appreciably each other's motions.

5. The ordinary shooting stars in their appearance and phenomena do not differ essentially from the individuals in star-showers.

6. The meteorites of different falls differ from one another in their chemical composition, in their mineral forms and in their tenacity. Yet through all these differences they have peculiar common properties which distinguish them entirely from all terrestrial rocks.

7. The most delicate researches have failed to detect any trace of organic life in meteorites.

These propositions have practically universal acceptance among scientific men. We go on to consider others which have been received with hesitation, or in some cases have been denied.

With a very great degree of confidence we may believe that shooting stars are solid bodies. As we see them they are discrete bodies, separated even in prolific star-showers by large distances one from another. We see them penetrate the air many miles, that is, many hundred times their own diameters at the very least. They are sometimes seen to break in two. They are sometimes seen to glance in the air. There is good reason to believe that they glance before they become visible.

Now, these are not the phenomena which may be reasonably expected from a mass of gas. In the first place, a spherical mass of matter at the earth's distance from the sun, under no constraint and having no expansive or cohesive power of its own, must exceed in density air at one-sixth of a millimeter pressure (a density often obtained in the ordinary air pumps) or else the sun by his unequal attraction for its parts will scatter it. Can we conceive that a small mass of gas, with no external constraint to resist its elastic force, can maintain so great a density?

But suppose that such a mass does exist, and that its largest and smallest dimensions are not greatly unequal; and suppose further that it impinges upon the air with a planetary velocity; could we possibly have as the visible result a shooting star? When a solid meteorite comes into the air with a like velocity its surface is burned or melted away. Iron masses and many of the stones have had burned into them those wonderful pittings or cupules which are well imitated, as M. Daubrée has shown, by the erosion of the interior of steel cannon by the continuous use of powder under high pressure. They are imitated also by the action of dynamite upon masses of steel near which the dynamite explodes. Such tremendous resistance that mass of gas would have to meet. The first effect would be to flatten the mass for it is elastic; the next to scatter it for there is no cohesion. We ought to see a flash instead of a long burning streak of light. The mass that causes the shooting star can hardly be conceived of except as a solid body.

Again, we may reasonably believe that the bodies that cause the shooting stars, the large fireballs and the stone-producing meteor, all belong to one class. They differ in kind of material, in

density, in size. But from the faintest shooting star to the largest stone-meteor we pass by such small gradations that no clear dividing lines can separate them into classes.

See wherein they are alike.

1. Each appears as a ball of fire traversing the apparent heavens just as a single solid but glowing or burning mass would do.

2. Each is seen in the same part of the atmosphere, and moves through its upper portion. The stones come to the ground, it is true, but the brightly luminous portion of their paths generally ends high up in the air.

3. Each has a velocity which implies an orbit about the sun.

4. The members of each class have apparent motions which imply common relations to the horizon, to the ecliptic, and to the line of the earth's motion.

5. A cloudy train is sometimes left along the track both of the stone-meteor, and of the shooting star.

6. They have like varieties of colors, though in the small meteors the colors are naturally less intense and are not so variously combined as in the large ones.

In short, if the bodies that produce the various kinds of fireballs had just the differences in size and material which we find in meteorites, all the differences in the appearances would be explained; while, on the other hand, a part of the likenesses that characterize the flights point to something common in the astronomical relations of the bodies that produce them.

This likeness of the several grades of luminous meteors has not been admitted by all scientific men. Especially it was not accepted by your late president, Professor J. Lawrence Smith, who by his studies added so much to our knowledge of the meteorites.

The only objection, however, so far as I know, that has been urged against the relationship of the meteorites and the star-shower meteors, and the only objection which I have been able to conceive that has apparent force, is the fact that no meteorites have been secured that are known to have come from the star-showers. This objection is plausible and has been urged both by mineralogists and astronomers as a perfect reply to the argument for a common nature to all the meteors.

But what is its real strength? There have been in the last one hundred years five or six star-showers of considerable intensity. The objection assumes that if the bodies then seen were like other meteors, we should have reason to expect that among so many hun-

dreds of millions of individual flights, a large number of stones would have come to the ground and have been picked up.

Let us see how many such stones we ought to expect. A reasonable estimate of the total number of meteors in all of these five or six star-showers combined makes it about equal to the number of ordinary meteors which come into the air in six or eight months. Inasmuch as we can only guess at the numbers seen in some of the showers let us suppose that the total number for all the star-showers was equal to one year's supply of ordinary meteors. Now the average annual number of stone-meteors of known date, from which we have secured specimens, has during this hundred years been about two and a half.

Let us assume then that the luminous meteors are all of like origin and astronomical nature; and further assume that the proportion of large ones, and of those fitted to come entirely through the air without destruction, is the same among the star-shower meteors as among the other meteors. With these two assumptions a hundred years of experience would then lead us to expect two, or perhaps three, stone falls from which we secure specimens during all the half dozen star-showers put together. To ask for more than two or three is to demand of star-shower meteors more than other meteors give us. The failure to get these two or three may have resulted from chance, or from some peculiarity in the nature of the rocks of Biela's and Tempel's comets. It is very slender ground upon which to rest a denial of the common nature of objects that are so similar in appearance and behavior as the large and small meteors.

It may be assumed then as reasonable that the shooting stars and the stone-meteors, together with all the intermediate forms of fireballs, are like phenomena. What we know about the one may with due caution be used to teach facts about the other. From the mineral and physical nature of the different meteorites we may reason to the shooting stars, and from facts established about the shooting stars we may infer something about the origin and history of the meteorites. Thus it is reasonable to suppose that the shooting stars are made up of such matter and such varieties of matter as are found in meteorites. On the other hand, since star-showers are surely related to comets, it is reasonable to look for some relation of the meteorites to the astronomical bodies and systems of which the comets form a part.

This common nature of the stone-meteor and the shooting stars

enables us to get some idea, indefinite, but yet of great value, about the masses of the shooting stars. Few meteoric stones weigh more than one hundred pounds. The most productive stone falls have furnished only a few hundred pounds each, though the irons are larger. Allowing for fragments not found, and for portions scattered in the air, such meteors may be regarded as weighing a ton, or it may be several tons, on entering the air. The explosion of such a meteor is heard a hundred miles around shaking the air and the houses over the whole region like an earthquake. The size and brilliancy of the flame of the ordinary shooting star are so much less than that of the stone-meteor that it is reasonable to regard the ordinary meteoroid as weighing pounds or even ounces, rather than tons.

Determinations of mass have been made by measuring the light and computing the energy needed to produce the light. These are to be regarded as lower limits of size, because a large part of the energy of the meteors is changed into heat and motion of the air. The smaller meteors visible to the naked eye may be thought of without serious error as being of the size of gravel stones, allowing, however, not a little latitude to the meaning of the indefinite word gravel.

These facts about the masses of shooting stars have important consequences.

The meteors, in the first place, are not the fuel of the sun. We can measure and compute within certain limits of error the energy emitted by the sun. The meteoroids, large enough to give shooting stars visible to the naked eye, are scattered very irregularly through the space which the earth traverses, but in the mean each is distant two or three hundred miles from its near neighbors. If these meteoroids supply the sun's radiant energy, a simple computation shows that the average shooting star ought to have a mass enormously greater than is obtained from the most prolific stone fall.

Moreover, if these meteoroids are the source of the solar heat their direct effect upon the earth's heat by their impact upon our atmosphere ought also to be very great: whereas the November star-showers in some of which a month's supply of meteoroids was received in a few hours do not appear to have been followed by noticeable increase of heat in the air.

Again the meteoroids do not cause the acceleration of the moon's

mean motion. In various ways the meteors do shorten the month as measured by the day. By falling on the earth and on the moon they increase the masses of both, and so make the moon move faster. They check the moon's motion and so bringing it nearer to the earth, shorten the month. They load the earth with matter which has no momentum of rotation, and so lengthen the day. The amount of matter that must fall upon the earth in order to produce in all these ways the observed acceleration of the moon's motion has [illegible]mputed by Prof. Oppolzer. But his result would requi[illegible]ch meteoroid an enormous mass, one far too great to be [illegible]pted as possible.

Again, the supposed power of such small bodies, bodies so scattered as these are even in the densest streams, to break up the comets or other heavenly bodies, and also their power by intercepting the sun's rays to affect our weather must in the absence of direct proof to the contrary be regarded as insignificant.

So too their effect in producing geologic changes by adding to the earth's strata has without doubt been very much over-estimated. During a million of years, at the present rate of say fifteen millions of meteors per day, there comes into the air about one shooting star or meteor for each square foot of the earth's surface.

To assume a sufficient abundance of meteors in ages past to accomplish any of these purposes is, to say the least, to reason from hypothetical and not from known causes.

The same may be said of the suggestion that the mountains of the moon are due to the impact of meteorites. Enormously large meteoroids in ages past must be arbitrarily assumed, and, in addition, a very peculiar plastic condition of the lunar substance in order that the impact of a meteoroid can make in the moon depressions ten, or fifty, or a hundred miles in diameter, surrounded by abrupt mountain walls two, and three, and four miles high, and yet the mountain walls not sink down again.

The known visible meteors are not large enough nor numerous enough to do the various kinds of work which I have named. May we not assume that an enormous number of exceedingly small meteoroids are floating in space, are falling into the sun, are coming into our air, are swept up by the moon? May we not assume that some of these various forms of work which cannot be done by meteoroids large enough for us to see them as they enter the air, are done by this finer impalpable cosmic dust? Yes, we may make

such an assumption. There exist no doubt multitudes of these minute particles travelling in space. But science asks not only for a true cause but a sufficient cause. There must be enough of this matter to do the work assigned to it. At present, we have no evidence that the total existing quantity of such fine material is very large. It is to be hoped that through the collection and examination of meteoric dust we may soon learn something about the amount which our earth receives. Until that shall be learned we can reason only in general terms. So much [illegible] coming into our atmosphere as these several hypotheses req[illegible]uld without doubt make its presence known to us in the appe[illegible] of our sunset skies, and in a far greater deposit of meteoric dust than has ever yet been proven.

A meteoroid origin has been assigned to the light of the solar corona. It is not unreasonable to suppose that the amount of the meteoroid matter should increase toward the sun, and the illumination of such matter would be much greater as we approach the solar surface. But it is difficult to explain upon such an hypothesis the radial structure, the rifts, and the shape of the curved lines that are marked features of the corona. These seem to be inconsistent with any conceivable arrangement of meteoroids in the vicinity of the sun. If the meteoroids are arranged at random there should be a uniform shading away of light as we go from the sun. If the meteoroids are in streams along cometary orbits, all lines bounding the light and shade in the coronal light should evidently be approximately projections of conic sections of which the sun's centre is the focus. There are curved lines in abundance in the coronal light, but as figured by observers and in the photographs they seem to be entirely unlike any such projections of conic sections. Only by a violent treatment of the observations can the curves be made to represent such projections. They look more as though they were due to forces at the sun's surface than at his centre. If those complicated lines have any meteoroid origin (which seems very unlikely) they suggest rather the phenomena of comets' tails than meteoroid streams or sporadic meteors.

The hypothesis that the long rays of light which sometimes have been seen to extend several degrees from the sun at the time of the solar eclipse are meteor streams seen edgewise seems possibly true, but not at all probable.

The observed life of the meteor is only a second, or at most a

few seconds, except when a large one sends down stones to remain with us. What can we learn about its history and origin?

Near the beginning of this century, when small meteors were looked on as some form of electricity, the meteorites were very generally regarded as having been thrown out from the lunar volcanoes. But as the conviction gained place that the meteorites moved not about the earth, but about the sun, it was seen that the lunar volcanoes must have been very active to have sent out such an enormous number of stones as are needed in order that we should so frequently encounter them. When it was further considered that there is no proof that lunar volcanoes are now active, and that when they were active they were more likely to have been open seas of lava, not well fitted to shoot out such masses, the idea of the lunar origin of the meteorites gradually lost ground.

But the unity of meteorites with shooting stars, if true, increases a hundred-fold the difficulty and would require that the comets have the same origin with the meteorites. No one claims that the comets came from the moon.

That the meteorites came from the earth's volcanoes is still maintained by some men of science, particularly by the distinguished Astronomer Royal for Ireland. The difficulties of the hypothesis are, however, exceedingly great.

In the first place, the meteorites are not like terrestrial rocks. Some minerals in them are like minerals in our rocks. Some meteoric irons are like the Greenland terrestrial irons. But no rock in the earth has yet been found that would be mistaken for a meteorite of any one of the two or three hundred known stone falls. The meteorites resemble the deep terrestrial rocks in some particulars, it is true, but the two are also thoroughly unlike.

The terrestrial volcanoes must also have been wonderfully active to have sent out such a multitude of meteorites as will explain the number of stone falls which we know and which we have good reason to believe have occurred.

The volcanoes must also have been wonderfully potent. The meteorites come to us with planetary velocities. In traversing the thin upper air, they are burned and broken by the resisting medium. Long before they have gone through the tenth part of the atmosphere the meteorites usually are arrested and fall to the ground. If these bodies were sent out from the earth's volcanoes they left the upper air with the same velocity with which they now

return to it. This the law of gravitation demands. What energy must have been given to the meteorite before it left the volcano to make it traverse the whole of our atmosphere, and go away from the earth with a planetary velocity! Is it reasonable to believe that volcanoes were ever so potent, or that the meteorites would have survived such a journey?

No one claims that the meteors of the star-showers nor that their accompanying comets came from the earth's volcanoes. To ascribe a terrestrial origin to meteorites is then to deny the relationship of the shooting star and the stone-meteor. Every reason for their likeness is an argument against the terrestrial origin of the stones.

To suppose that the meteors came from any planets that have atmospheres involves difficulties not unlike to, and equally serious with, those of a terrestrial origin.

The solar origin of meteorites has been seriously urged, and deserves a serious answer.

The first difficulty which this hypothesis meets is, that solid bodies should come from the hot sun. Besides this, they must have passed without destruction through an atmosphere of immense thickness, and must have left the sun with an immense velocity.

Then there is a geometric difficulty. The meteorite shot out from the sun would travel under the law of gravitation nearly in a straight line outward and back again into the sun. If in its course it enters the earth's atmosphere, its relative motion, that which we see, should be in a line parallel to the ecliptic, except as slightly modified by the earth's attraction. A large number of these meteors, that is most, if not all, well observed fireballs, have certainly not travelled in such paths. These did not come from the sun.

It has been a favorite hypothesis that the meteorites came from some planet broken in pieces by an internal catastrophe. There is much which mineralogists can say in favor of such a view. The studies of M. Stanislas Meunier and others into the structure of meteorites have brought out many facts which make their hypothesis plausible. It requires, however, that the stone-meteor be not regarded as of the same nature as the star-shower meteor, for no one now seriously claims that the comets are fragments of a broken planet. The hypothesis of the existence of such a planet is itself arbitrary; and it is not easy to understand how any mass that has

become collected by the action of gravity and of other known forces should by internal forces be broken in pieces, and these pieces rent asunder. The disruption of such a planet by internal forces after it has by cooling lost largely its original energy would be specially difficult to explain.

We cannot then look to the moon, nor to the earth, nor to the sun, nor to any of the large planets, nor to a broken planet as the first home of the meteoroids, without seeing serious if not insuperable objections. But since some of the meteoroids were in time past certainly connected with comets, and since we can draw no line separating shooting stars from stone-meteors, it is most natural to assume that all of them are of a cometary origin. Are there any insuperable objections that have been urged against the hypothesis that all of the meteoroids are of like nature with the comets, that they are in fact fragments of comets, or it may be in some cases, minute comets themselves?

If such objections exist they ought evidently to come mainly from the mineralogists, and from what they find in the internal structure of the meteorites. Astronomy has not as yet furnished any objections. It seems strange that comets break in pieces, but astronomers admit it for it is an observed fact. It is strange that groups of these small bodies should run before and follow after comets along their paths, but astronomers admit it as a fact in the case of at least four comets. Astronomically, there would seem to be no more difficulty in giving such origin to the sporadic meteor, and to the large fireball, and to the stone-meteor, than there is in giving it to the meteor of the star-shower. If then the cometic origin of meteorites is inadmissible, the objections must come mainly from the nature and structure of meteoric stones and irons. Can the comet in its life and history furnish the varied conditions and forces necessary to the manufacture or growth of these peculiar structures?

It is not necessary in order to answer this question to solve the thousand puzzling problems that can be raised about the origin and the behavior of comets. Comets exist in our system, and have their own peculiar development, whatever be our theories about them. It will be enough for my present purpose to assume, as probably true, the usual hypothesis that they were first condensed from nebulous matter; that that matter may have been either the outer portions of the original solar nebula, or matter

entirely independent of our system and scattered through space.

In either case the comet is generally supposed, and probably must be supposed, to have become aggregated far away from the sun. This aggregation was not into one large body to be afterwards broken up by disruption or by solar action. The varieties of location of the cometic orbits seem inexplicable upon any such hypothesis. Separate centres of condensation are to be supposed but they are not *a priori* unreasonable. This is the rule rather than the exception everywhere in nature. Assume then such a separate original condensation of the comet in the cold of space, and that the comet had a very small mass compared with the mass of the planets. Add to this the comet's subsequent known history as we are seeing it in the heavens. Have we therein known forces and changes and conditions of such intensity and variety as the internal structure of the meteorites calls for?

What that structure is, and to some extent what conditions must have existed at the time and place of its first formation and during its subsequent transformations, mineralogists rather than astronomers must tell us. For a long time it was accepted without hesitation that these bodies required great heat for their first consolidation. Their resemblance to the earth's volcanic rocks was insisted on by mineralogists. Professor J. Lawrence Smith in 1855 asserted without reserve that " they have all been subject to a more or less prolonged igneous action corresponding to that of terrestrial volcanoes." Director Haidinger, in 1861, said " With our present knowledge of natural laws these characteristically crystalline formations could not possibly have come into existence except under the action of high temperature combined with powerful pressure." The likeness of these stones to the deeper igneous rocks of the earth as shown by the experiments of M. Daubrée strengthened this conviction.

Mr. Sorby in 1877 said, " It appears to me that the conditions under which meteorites were formed must have been such that the temperature was high enough to fuse stony masses into glass; the particles could exist independently one of the other in an incandescent atmosphere, subject to violent mechanical disturbances; that the force of gravitation was great enough to collect these fine particles together into solid masses, and that these were in such a situation that they could be metamorphosed, further broken up into fragments, and again collected together."

Now if meteorites could come into being only in a heated place, then the body in which they were formed ought, it would seem, to have been a large one. But the comets, on the contrary, appear to have become aggregated in small masses.

The idea that heat was essential to the production of these minerals was at first a natural one. All other known rock formations, are the result of processes that involved water or fire or metamorphism. All agree that the meteorites could not have been formed in the presence of water or free oxygen. What conclusion was more reasonable than that heat was present in the form of volcanic or of metamorphic action?

The more recent investigations of the meteorites and kindred stones, especially the discussions of the Greenland native irons and the rocks in which they are imbedded, are leading mineralogists, if I do not mistake, to modify their views. Great heat at the first consolidation of the meteoric matter is not considered so essential. In a late paper M. Daubrée says, "It is extremely remarkable that in spite of their great tendency to a sharply defined (*nette*) crystallization, the silicate combinations which make up the meteorites are there only in the condition of very small crystals all jumbled together as if they had not passed through fusion. If we may look for something analogous about us, we should say that instead of calling to mind the long needles of ice which liquid water forms as it freezes, the fine grained texture of meteorites resembles rather that of hoar frost and that of snow, which is due, as is known to the immediate passage of the atmospheric vapor of water into the solid state."

So Dr. Reusch from the examination of the Scandinavian meteorites concludes that "there is no need to assume volcanic and other processes taking place upon a large heavenly body formerly existing but which has since gone to pieces."

The meteorites resemble the lavas and slags on the earth. These lavas and slags are formed in the absence of water, and with a limited supply of oxygen, and heat is present in the process. But is heat necessary for the making of the meteorites? Some crystallizations do take place in the cold; some are direct changes from gaseous to solid forms. We cannot in the laboratory reproduce all the conditions of crystallization in the cold of space. We cannot easily determine whether the mere absence of oxygen will not account fully for the slag-like character of the meteorite minerals.

Wherever crystallization can take place at all, if there are present silicon and magnesium and iron and nickel with a limited supply of oxygen, there silicates ought to be expected in abundance, and the iron and nickel in their metallic form. Except for the heat the process should be analogous to that of the reduction of iron in the Bessemer cupola where the limited supply of oxygen combines with the carbon and leaves the iron free. The smallness of the comets should not then be an objection to considering the meteoric stones and irons as pieces of comets. There is no necessity of assuming that they were parts of a large mass in order to provide an intensely heated birth-place.

But although great heat was not needed at the first formation there are many facts about these stones which imply that violent forces have in some way acted during the meteorites' history. The brecciated appearance of many specimens, the fact that the fragments in a breccia are themselves a finer breccia, the fractures, infiltrations and apparent faultings seen in microscopic sections, and by the naked eye,—these all imply the action of force.

M. Daubrée supposes that the union of oxygen and silicon furnishes sufficient heat for making these minerals. If this be possible those transformations may have taken place in their first home. Dr. Reusch argues that the repeated heating and cooling of the comet as it comes down to the sun and goes back again into the cold is enough to account for all the peculiarities of structure of the meteorites. These two modes of action do not however exclude each other.

Suppose then, a mass containing silicon, magnesium, iron, nickel, a limited supply of oxygen and small quantities of other elements, all in their primordial or nebulous state (whatever that may be) segregated somewhere in the cold of space. As the materials consolidate or crystallize, the oxygen is appropriated by the silicon and magnesium, and the iron and nickel are deposited in metallic form. Possibly the heat developed may, before it is radiated into space, modify and transform the substance. The final result is a rocky mass (or possibly several adjacent masses) which sooner or later is no doubt cooled down throughout to the temperature of space.

This mass in its travels comes near to the sun. Powerful action is there exerted upon it. It is heated. How intense is that heat upon a cold rock unprotected apparently by its thin atmos-

phere, it is not possible to say. We know that the sun's action is strong enough to develop and drive off into space, that immense train, the comet's tail, that sometimes spans our heavens. It is broken in pieces. We have seen the portions go away from the sun, to come back probably as separate comets. Solid fragments are scattered from it to travel in their own independent orbits.

What is the condition of the burnt and crackled surface of a cometic mass or fragment as it goes out from near the sun again into the cold? What changes and recrystallizations may not that surface undergo before it comes back to pass anew through the fiery ordeal? We have here forces that we know are acting. They are intense, and act under varied conditions. The stones subject to those forces can have a history full of all the scenes and actions required for the growth of such strange bodies as have come down to us. Some of our meteors, those of the star-showers, have certainly had that history. What good reason is there for saying that all of them may not have had the like birthplace and life?

Before I close let me recite one lesson that has been taught us by the recent star-showers. The pieces which come into our air, in any recurring star-shower, belong to a group whose shape is only partly known. It is thin, for we traverse it in a short time. It is not a uniform ring, for it is not annual, except possibly the August sprinkle. How the sun's unequal attraction for the parts of a group acts as a dispersive force to draw it out into a stream, those most beautiful and most fruitful discussions of Signor Schiaparelli have shown. The groups that we meet are certainly in the shape of thin streams.

It has been assumed that the cometic fragments go continuously away from the parent mass so as to form in due time a ringlike stream of varying density, but stretched along the entire elliptic orbit of the comet. The epochs of the Leonid star-showers in November, which have been coming at intervals of thirty-three years since the year 902, have led us to believe that this departure of the fragments from Tempel's comet (1866, I) and the formation of the ring was a very slow process. The meteors which we met near 1866, were, therefore, thought to have left the comet many thousand years ago. The extension of the group was presumed to go on in the future, until, perhaps tens of thousands of years hence, the earth shall meet the stream every year.

Whatever may be the case with Tempel's comet and its meteors, this slow development is not found to be true, for the fragments of Biela's comet. It is quite certain that the meteors of the splendid displays of 1872 and 1885 left the immediate vicinity of that comet later than 1840, although at the time of those showers they had become separated two hundred millions of miles from the computed place of the comet. The process then has been an exceedingly rapid one, requiring, if continued at the same rate, only a small part of a millennium for the completion of an entire ring, if a ring is to be the finished form of the group.

It may be thought reasonable in view of this fact about Biela's comet established by the star-showers of 1872 and 1885 to revise our conception of the process of disintegration of Tempel's comet also. The more brilliant of the star-showers from this comet have always occurred very near the end of the thirty-three year period. Instead of there being a slow process which is ultimately to produce a ring along the orbit of the comet, it certainly seems more reasonable to suppose that the compact lines of meteors which we met in 1866, 1867 and 1868 left the comet at a recent date. A thousand years ago this shower occurred in the middle of October. By the precession of the equinoxes and the action of the planets, the shower has moved to the middle of November. One-half of this motion is due to the precession of the equinoxes, the other half to the perturbing action of the planets. Did the planets act upon the comet before the meteoroids left it, or upon the meteoroid stream? Until one has reduced the forces to numerical values, he may not give to this question a positive answer. But I strongly suspect that computations of the forces will show that the perturbations of Jupiter and Saturn upon that group of meteoroids hundreds of millions of miles in length, perturbations strong enough to change the node of the orbit fifteen degrees along the ecliptic, would not leave the group such a compact train as we found it in 1866. If this result is at all possible, it is because the total action is scattered over so many centuries. But it seems more probable that the perturbation was of the comet itself, that the fragments are parting more rapidly from the comet than we have assumed, and that long before the complete ring is formed the groups become so scattered that we do not recognize them, or else are turned away so as not to cross the earth's orbit.

Comets by their strange behavior and wondrous trains have given to timid and superstitious men more apprehensions than have any other heavenly bodies. They have been the occasion of an immense amount of vague and wild and worthless speculation by men who knew a very little science. They have furnished a hundred as yet unanswered problems which have puzzled the wisest. A world without water, with a strange and variable envelope which takes the place of an atmosphere, a world that travels repeatedly out into the cold and back to the sun and slowly goes to pieces in the repeated process, has conditions so strange to our experience and so impossible to reproduce by experiment that our physics cannot as yet explain it. Yet we may confidently look forward to the answer of many of these problems in the future. Of those strange bodies, the comets, we shall have far greater means of study than of any other bodies in the heavens. The comets alone give us specimens to handle and analyze. Comets may be studied, like the planets, by the use of the telescope, the polariscope and the spectroscope. The utmost refinements of physical astronomy may be applied to both. But the cometary worlds will be also compelled, through these meteorite fragments with their included gases and peculiar minerals, to give up some additional secrets of their own life and of the physics of space to the blowpipe, the microscope, the test-tube and the crucible.

REPORTS OF COMMITTEES.

Report of the Committee on Indexing Chemical Literature[1].

In presenting their Fourth Annual Report the Committee is pleased to record gratifying evidences of a wide and growing interest in the bibliographical work which it is designed to encourage and aid. During the past year the correspondence conducted by the Chairman has been three-fold greater than in any previous year, and the subjects referred to the committee have increased in diversity much beyond expectation, until they include important questions in general chemical bibliography. Some of these questions pertain to matters which require for their solution an authority which the committee is unwilling to claim or assume; such for instance is the question of uniformity in abbreviations of chemical periodicals, the desirability of which is admitted, while the feasibility of devising a list of abbreviations which would be regarded as authoritative is doubtful. One of the committee discusses this subject in a communication to the Chemical Section, appended to this Report, and to this we relegate further consideration.

INDEXES PUBLISHED.

Bibliography of Petroleum, by Professor S. F. Peckham. Report on the Production, Technology and Uses of Petroleum and its Products. Report of the tenth census of the United States, Vol. X, 1884, 4to; pages 281-301. [A comprehensive bibliography of *Bitumen* and its related subjects.]

Bibliography of the Metal Iridium, by Nelson W. Perry, in Prof. W. L. Dudley's paper on Iridium published in Mineral Resources of the United States, calendar years 1883 and 1884. Washington, 1885. 8vo.

An Index to the Literature of Uranium 1789-1885. By H. Carrington Bolton. Smithsonian Report for 1885. Washington, 1885, 36 pp. 8vo.

[1] Read before the Chemical Section of the American Association for the Advancement of Science, August, 1886.

It is almost superfluous to call attention to the following superb work, yet for sake of completeness it may be here recorded:

Melting- and Boiling-Point Tables. Physico-chemical Constants. By Thomas Carnelley. Vol. I, London, 1885. 350 pp. Royal 4to, [To be completed in two volumes comprising about 50,000 melting and boiling point data.]

REPORTS OF PROGRESS.

Professor William Ripley Nichols has done a great deal of work on the Index to Carbon-monoxide but defers printing another year.

Professor Charles E. Munroe reports he is ready to print a section of his extensive Index to the Literature of Explosives.

Professor L. P. Kinnicutt is engaged on a Bibliography of Meteorites.

Dr. F. E. Engelhardt is compiling an Index to the Literature of Common Salt.

PROJECTED BIBLIOGRAPHIES.

Professor F. W. Clarke has nearly ready for the press a new edition of his *Specific Gravity Tables*, Constants of Nature, Part I. This edition will contain about twice as much matter as the original work, although melting and boiling points are omitted, these having been catalogued by Dr. Carnelley in the work above mentioned.

Professors William Ripley Nichols and Lewis M. Norton are engaged on a *Dictionary of Chemical Synonymes* which will prove a valuable contribution to chemical bibliography and of practical utility to chemists.

Mr. S. P. Sharples, of Boston, informed the committee in November, 1885, of his willingness to complete an *Index to the Literature of Milk Analysis* which he had compiled several years before; and a few weeks later, Mr. Clement W. Andrews, of the Massachusetts Institute of Technology, notified the committee of a similar undertaking which he proposed perfecting and bringing down to date. These two gentlemen were at once put into communication and a mutual understanding has been reached whereby useless duplication will be avoided.

Professor Stephen F. Peckham, of Providence, R. I., whose voluminous Bibliography of Petroleum is noticed above, is engaged on a continuation of the work which he plans to bring down to 1890.

Professor William H. Seaman, of the U. S. Patent Office, calls attention to the important literature of chemistry found in Patent Specifications, and proposes to compile an *Index to American Chemical Patents*, for which undertaking he has unusual facilities.

Professor Erastus G. Smith, of Beloit, has begun an *Index to the Literature of Aluminium*, a topic suggested by the committee.

Mr. George F. Kunz, of Hoboken, is collecting and indexing works relating to *Gems and Precious Stones*. His bibliography already numbers 2000 titles and will treat of the subject in a comprehensive manner, including facts relating to the history, mining, cutting, uses, and literature of gems in all languages.

Mr. William Beer, late of the College of Physical Science, Newcastle-on-Tyne, availing himself of facilities afforded by the Library of the University of Michigan, is engaged on a *Bibliography of Scientific Bibliographies*, the first part of which he intends soon to offer to the committee; he has also in an advanced state a *Bibliography of Copper*.

The committee desires to record thanks to the American Association for the Advancement of Science for reprints of reports furnished free of charge, and also to the Smithsonian Institution which gratuitously distributed the reports to chemists and others.

The committee again appeals to chemists for support, and calls for volunteers to undertake indexes to special topics in chemical literature, especially the chemical elements. The committee dictates no fixed plan but leaves method and subject to authors; the committee does not seek to control the productions further than to insure work of high merit and to guard the interests of the Smithsonian Institution which has agreed to publish manuscripts endorsed by the committee. Sample copies of Indexes and other information can be obtained by addressing the chairman care of the Smithsonian Institution.

H. CARRINGTON BOLTON, *Chairman*.
IRA REMSEN,
F. W. CLARKE,
ALEXIS A. JULIEN.

July, 1886.

NOTE. Since writing the above the death of Prof. Wm. Ripley Nichols is announced. —— Absence from the country has prevented Prof. Albert R. Leeds from signing the above Report.

APPENDIX TO REPORT OF COMMITTEE ON INDEXING CHEMICAL LITERATURE.

A PROBLEM IN CHEMICAL BIBLIOGRAPHY.

By H. Carrington Bolton.

It is no disparagement to the profession to say that not all chemists are bibliographers; the peculiar talents and skill which ensure success in laboratory researches have no necessary connection with the technical erudition of bibliography. In preparing for publication records of their researches, chemists generally aim to chronicle the previous labors of others in the same or analogous lines, but in quoting from periodicals the writers sometimes give little thought to their accurate and systematic designation. A lack of uniformity is especially marked in the abbreviations by which the journals are indicated, these abbreviations often requiring for their comprehension a "scientific use of the imagination." Many circumstances, national and individual, combine to produce confusion; the customs of divers countries vary greatly, and when English-speaking chemists adopt the abbreviations of French titles in use by German authorities, the result is not satisfactory from a bibliographical standpoint. The different tastes of some individuals, the thoughtlessness of others who seldom write a title twice in the same way, lead to the employment of many abbreviations for a single journal. Lest we may be accused of exaggeration we give a single example of this multiplicity of abbreviations; the voluminous and influential *Berichte der deutschen chemischen Gesellschaft zu Berlin* is referred to by writers in the following ways:

B.
Ber.
Ber. d. chem. Ges.
Ber. d. deutsch. chem. Gesellsch.
Ber. Berl. chem. Ges.
Berl. Ber.
Berichte.
D. C. Ges.
Deutsch. ch. Ges. Ber.

and doubtless in many more variations. Many other instances will occur to our readers who need no arguments to admit the desirability of a reasonable degree of uniformity in abbreviations of this kind.

When engaged in compiling "A Catalogue of Chemical Periodicals" (New York, 1885) the writer contemplated adding thereto a list of abbreviations of the titles catalogued, but a sense of the inexpediency and futility of an assumption of authority caused an abandonment of the plan. Recently the subject has been broached by correspondents of the Com-

mittee on Indexing Chemical Literature, and a statement of the case seems advisable.

The existing lists of abbreviations for chemical periodicals, having a degree of completeness and possible authority, are not numerous. That monumental work of the Royal Society: "A Catalogue of Scientific Papers (1800–'63)," 7 vols., 4to, 1867–77, London, is the first to which one in search of reliable data would turn, but unfortunately this great work is bibliographically very unsatisfactory. The abbreviations of titles follow no definite plan, the first word abbreviated is sometimes the place of publication, sometimes the editor, and sometimes the first word of the title. We find such inversions as "Geol. Soc. Proc.", such redundant expressions as "*Gistl, Faunus*," and other evidences of a lack of system and of economy of space. The abbreviations in this catalogue cannot be adopted as standard.

Several chemical journals which furnish their readers with abstracts of contemporary literature have their own lists of abbreviations, but these are limited to journals now current, and the host of discontinued journals remain unprovided for. Nor are the abbreviations used by any means ideal: thus we find in the valued *Jahresbericht * * * der Chemie*, several objectionable abbreviations, such as "Sill. Am. J." for the veteran American periodical which was so long associated with the name of Silliman; "Lond. R. Soc. Proc." in which the disorder is objectionable, an objection also applicable to the abbreviation "*Russ. Zeitschr. Pharm.*"

In Mr. S. H. Scudder's Catalogue of Scientific Serials, we find an "Index to Titles" which is suggestive in many points although not prepared for use as abbreviations; nor does it give the abbreviations of Society transactions, the words Annals, Berichte, Journal, Bulletin, etc., being dropped for convenience. The care with which the abbreviated titles were prepared is, however, manifest in the skilful differentiation of expressions similar in orthography.

The most systematic and extended list of abbreviations of journal-titles appears to be that accompanying the Index-Catalogue of the Library of the Surgeon-General's Office, U. S. A. (Washington, 1880), and prepared by Drs. Billings and Fletcher. In this the authors clearly lay down the following principles for the construction of abbreviations on a uniform plan.

1. To follow the exact order of words of the title.
2. To make the abbreviations as brief as is consistent with clearness to those familiar with medical literature.
3. To follow strictly the orthographical usages of each language. This disposes of the question of capitalization.
4. To attain uniformity as far as possible.
5. The place of publication is generally added.

This work is intended for medical journals exclusively, but includes naturally a considerable number of chemical works. In the rules above quoted we find a basis for action, a definite method applicable to periodicals of every department of learning. While admiring the perspicuity of

the contractions, the high degree of uniformity attained, and the consistency with which the rules are applied, we are, nevertheless, of the opinion that the abbreviations in this Index-Catalogue are in many cases unnecessarily long and cumbersome. This arises partly from retaining the initials of articles occurring in the title, partly from frequent addition of the place of publication even when it does not form part of the title, and largely from the praiseworthy attempt to be consistent, especially in applying rule 1. A single example taken from chemistry, will suffice to illustrate the occasion of our criticism. The well known journal popularly known as "*Berzelius' Jahresbericht*" has assigned to it the following abbreviation: "*Jahresb. ü. d. Fortschr. d. phys. Wissensch. v. Berzelius, Tübing.*" This work is one of many having similarly unwieldy titles, and surely the abbreviation just given errs in like manner; chemists hastily noting the source of a reference cannot be expected to employ abbreviations of this character. Briefly, they are too consistent to be expedient.

Many journals, which have been conducted for a long series of years by a single editor of distinction, are known by that editor's name joined to the principal word of the title. While this is perhaps admissible in colloquial speech, abbreviations of these conventional titles are sometimes obscure and perplexing. Again, journals are sometimes quoted by prefixing the place of publication to the contracted titles, and this is another source of confusion. The propriety of avoiding these abbreviated, conventional titles in references is unquestionable, yet the most ardent adherent of bibliographical accuracy will hardly succeed in inducing chemists to forego speaking in such well established phrases as Silliman's Journal, Poggendorff's Annalen, Wagner's Jahresbericht and Dingler's Journal, notwithstanding the fact that no persons of these names are longer connected with the respective periodicals. We do not believe perfect consistency between the spoken names and written abbreviations either necessary or desirable. On the other hand, the adoption of different names for different series of the same periodical, merely because a new editor has come into control, is a method of giving references which in our opinion cannot be too strongly condemned. In an exceedingly valuable work of reference, published last year, the author who adopts this unfortunate method designates a well known journal by no less than three sets of abbreviations, and is forced to admit in his preface that these are not always correctly applied. When the change of editorship is accompanied by renumbering of volumes the objection has less weight.

Many of the existing lists of abbreviations are designed to fill a special need in a particular work and are not suited to general use. This is true of the abbreviations in Dr. Carnelley's Melting and Boiling Point Tables, where restricted space demanded utmost condensation. In these Tables the single letter "A" stands for Annalen der Chemie, "B," for the Berichte der deutschen chemischen Gesellschaft, "J" for Jahresbericht * * der Chemie, etc.

This suggests that the methods of designating periodicals may for con-

venience be classified in two groups, those in which a single letter is used, or at most two or three initials somewhat arbitrarily chosen, and second, those consisting of contractions of the words of the title; the first style may be called symbols, and the second contractions; both these classes occur in the abbreviations in general use.

The Problem in Chemical Bibliography which we have sketched in a desultory way is one which concerns not merely chemistry but the whole range of scientific literature. We think, however, that each branch of science should find its own interested expositors, and for this and other reasons we here limit the question to subjects properly coming before the Chemical Section.

The Problem has a two-fold aspect; first, in what way can a standard list of abbreviations of chemical periodicals be best prepared? and, secondly, How can such a standard list be presented to American chemists in a way to secure the widest acceptance? We propose that a coöperative effort be made to solve this problem, and suggest that it be referred to the Committee on Indexing Chemical Literature, reinforced by two bibliographers, to be added to its membership.

Trinity College, Hartford, August, 1886.

FOURTH REPORT OF THE COMMITTEE ON STANDARDS OF STELLAR MAGNITUDES.

The request was made in the last report of this committee that very faint stars might be looked for in certain regions with telescopes of the largest size. The regions were those following the stars γ *Pegasi*, ϵ *Orionis*, η *Virginis*, and η *Serpentis* from two to six minutes of time, and within five minutes of arc north or south of the principal stars. To those should be added the region within five minutes of arc of the north pole. A statement of all the stars visible in these regions with smaller telescopes is also very desirable. Important observations have been received in compliance with this request, but as some of them are still incomplete, it is deemed best to extend to July 1, 1887, the period within which the results must be received at the Harvard College Observatory, Cambridge, U.S., in order that they may be useful for the present purpose. Measures made of the other stars proposed as standards will also be included in the next report if received before the date already mentioned.

Respectfully submitted,

EDWARD C. PICKERING, *Chairman.*
S. W. BURNHAM,
ASAPH HALL,
WILLIAM HARKNESS,
EDWARD S. HOLDEN,
SIMON NEWCOMB,
ORMOND STONE,
C. A. YOUNG.

REPORT OF THE COMMITTEE ON "PHYSICS TEACHING."

MEETINGS of the committee have been held, since the beginning of the present session of the A. A. A. S., a majority of the committee being present. The National Educational Association having appointed a committee to report upon the same subject, a conference was had with representatives of this committee, at which it was agreed that it was extremely desirable for the two committees to come to a common agreement regarding the principal conclusions likely to be reached, and to that end a meeting of the two committees in conference at some time in the coming year should be arranged for. It is hoped that this may be accomplished, and the matter of a suitable time and place is now under consideration.

Although your committee has discussed at some length the leading features of the question referred to it and might be able to agree upon a report at this time, in view of the great importance of coming to a complete agreement with the representatives of the National Educational Association, it respectfully requests that it be continued for another year.

T. C. MENDENHALL, *Chairman.*

Report of progress of committee on deaths, births and marriages.

As chairman of the Committee on the Registration of Deaths, Births and Marriages, I ask that the committee be continued.

The subject has been before committees of the senate of the United States in several previous congresses, but has not yet been acted upon, although its importance has been acknowledged by those who have considered the matter. It is believed that favorable action will be taken thereon at an early day.

I have conferred with several U. S. senators and representatives, and also with Hon. Hugh S. Thompson, one of the assistant secretaries of the treasury, who, as a former governor of South Carolina, has had experience relative to this fundamental and exact branch of social science.

It seems probable, if the subject be pressed upon the attention of Congress early in the next session, that that body may be willing to authorize and require such measures to be taken as will soon bring about a coöperation between the government of the United States and the governments of the several states and territories in the establishment of a common, uniform and efficient system of registration of deaths, births and marriages.

This information, if obtained, will be useful not only in determining the descent of heritable property, which, on an average for the whole property-holding population, changes ownership by death about three times in a century, but also in determining the relative salubrity of localities and correct tables of the mean duration of human life and of life annuities for this country and the various sections thereof, for the use of courts of law, of beneficent institutions, and for subserving the public interest at large.

E. B. Elliott,
Chairman of Committee.

REPORT OF COMMITTEE ON INTERNATIONAL SCIENTIFIC CONGRESS.
CHARLES S. MINOT, *Secretary*, reporter.

FURTHER correspondence has been conducted with the committee of the British Association in regard to holding a meeting in London, and the matter will be laid before the British Association at its approaching meeting for definite action. Until the decision as to the action of the British Association is reached, further steps on our part are deemed inexpedient. Your committee therefore reports progress and asks to be continued.

Report of the American committee of the international congress of geologists. Persifor Frazer, reporter.

In pursuance of the order of the American Committee of the International Congress of Geologists at its meeting held in the Murray Hill Hotel, New York City, on May 22, 1886, the secretary presents to the American Association for the Advancement of Science the following report of the work of your committee during the past year.

At the meeting of the Standing Committee of the A. A. A.S., during the last session of the latter body, there were added to the American Committee of the Geological Congress, Prof. H. S. Williams, Prof. N. H. Winchell, and Dr. Persifor Frazer (as appears by the official record of the permanent secretary). By some misfortune, Prof. Winchell's appointment was not known to the members of the American Committee until the report to be alluded to later was printed, so that his name does not appear in the list of members of the committee, as it should, on page two of the report.

As soon as the secretary learned the facts, he printed an extra leaf containing Prof. Winchell's name and the reason for its non-appearance on the first three hundred copies of the pamphlet, and inserted this leaf into each of the remaining copies up to that time unsold; besides mailing it to every member of the committee.

The members of the American Committee who were present at the opening session of the Congress were, Prof. James Hall (President), Prof. J. S. Newberry, M.D., Prof. H. S. Williams and Dr. Persifor Frazer.

Prof. George J. Brush, happening to be in Berlin at the time, was elected by the American Committee's representatives above named an acting member of the committee during the session of the Congress.

Other Americans in Berlin at the time were enrolled by the Congress's Committee of organization as members of the Congress, viz.: Mr. W. J. McGee of the United States Geological Survey Messrs. Kemp, Miller and Patton.

The opening session of the Congress was on Monday, September 28, and the closing session on Saturday, October 3. The sub-

jects discussed at the formal meetings as well as those treated by savants of different countries at the extra sessions of the Congress were of wide range, and their influence was great in aiding the objects for which the Congress was originally created. For a detailed account of these discussions and the reports of the various committees the secretary refers to the pamphlet before mentioned and herewith submitted.

The basis of the discussions was the work of the two International Committees appointed by the Congress to propose plans, first, for the uniformity of nomenclature of geological science (the limitations of the groups and series by reference to existing and well known horizons, etc., etc.); and, second, for a geological map of Europe which should employ for the grand divisions colors and symbols which could be readily accepted by all geologists as a universal sign-language, while leaving the individual explorer as untrammelled as possible in delineating details. Both these Committees had been appointed at a previous session of the Congress, and each had held meetings previous to the Berlin session. The reports of these committees were considered and voted on clause by clause and a very large proportion of the views they contained were endorsed by the Congress. In some instances the questions were adjourned to a subsequent session of the Congress, and in others discretion was granted the Committee to mature its own plans and to submit its final results when completed. There was a marked absence of any attempt on the part of the directors of the proceedings to influence the decision of the responsible body, or to introduce into the discussions a narrow partisanship for this or that school. To judge by the subsequent criticisms of the work of the Congress, which were made by some of those whose suggestions were not always adopted by that body, it cannot be denied that very encouraging progress has been made towards, and many useless obstacles cleared away from, the construction of a consistent and enduring framework upon which to attach the facts of the science which have been and remain to be discovered.

At a meeting of the American Committee held in the Reichstagsgebäude, before the opening of the Congress, Prof. James Hall was elected President and Dr. Persifor Frazer was elected Secretary. The secretary was instructed to enquire by cable of the N. Y. Tribune whether it was willing to assume the expense of transmission of a daily cable message giving a succinct summary of the more important events of each session. No response was received to

this despatch and it appears on investigation by the managing e
itor of the N. Y. Tribune that no such despatch was ever receiv
in New York. After the adjournment of the Congress the Secr
tary, with the kind assistance of Prof. H. S. Williams, wrote o
the notes which he had taken during its debates, and forward
them to Professor Hitchcock for publication in the American Jou
nal of Science. This matter was in type but still unpublish
when your secretary returned to the United States, so that he w
able to correct the revise before it appeared.

Your secretary is very much gratified to be enabled to state th
after copies of this report had been mailed to all, and answers r
ceived from almost all of those who took a prominent part in the wo
of the Congress, no important corrections were suggested except b
Professors Newberry, Dewalque, and de Lapparent. Professor D
walque objected to the statement of the question decided by a vo
of the Congress on motion of Dr. Geikie on the second day, an
relating to a division of the *Devonian*. The statement as made
a condensed summary written for "Science" accorded with the u
derstanding of the matter by a number of members of the Congre
(both European and American) whom the writer consulted; but
view of the fact that the official report must decide the question, th
phrase was amended so as to leave the exact wording of the res
lution to be settled by this authority.

The error in the case of Professor de Lapparent's remarks wa
due to indistinctness of the notes at that place; and Professor d
Lapparent's own words were substituted in the report subsequent
published by the committee, as were also those of Professor New
berry in the part relating to his remarks.

It may be permitted to add here that this report of the procee
ings of the Congress was made from such long-hand notes as th
writer took during the sessions, and without the help or correctio
of any person, or access to the official minutes of the stenographer

Taking these facts in connection with the universally condemne
acoustic qualities of the hall, and the obstacles to clearness whic
resulted from the fact that French, the official language of the Co
gress's deliberations, was not the mother tongue of the majorit
of those who spoke, it was with more than ordinary satisfactio
that the writer received a letter from the official secretary, Mr. Fo
tannes, who is in possession of all the short-hand notes, endorsin
the "rigid accuracy" of the account.

Professor Hall called a meeting of the American Committee i

the Windsor Hotel, New York City, for Friday, Jan. 8, 1886, at which were present Professors Hall, Hunt, Newberry, Hitchcock, Stevenson, Cook and Frazer. Mr. McGee was by vote admitted to the deliberations of the committee as the representative of Major Powell.

The Committee ordered Dr. Frazer to prepare and print a report of the proceedings of the Congress together with either translations of the full report, or an English digest of the reports of the International and National Committees of the Congress: and to order from Berlin the number of copies of the proposed international color-scale necessary to accompany the edition.

It was agreed that the expense of issuing this work should be borne by the members of the American Committee and that the copies should be sold at fifty cents each; which it was then thought would cover it. Circulars were addressed to all the members of the geological section of the Association, as well as to those on an exchange list of geologists furnished by the United States Geological Survey; and to all the names in Cassino's "Scientists' Directory of 1882–83" to which were affixed "Geol." or "Palæo." This led to numerous applications for the pamphlet, and about 320 of the 600 have thus far been disposed of. The committee further directed the preparation of an appeal to the geological surveys and geologists of this country urging as full a compliance as possible with the recommendations of the Congress.

It was ordered that a sub-committee be appointed to discuss the attitude of American geologists towards the several questions which the Congress has yet to consider. At a subsequent meeting this sub-committee was greatly enlarged, and each member was assigned to one or the other of the separate divisions of the geological column, with instructions to prepare a report for presentation at a meeting of the sub-committee to be held prior to Feb. 1, 1887.

Another sub-committee was directed to take steps toward securing the coöperation of institutions of learning and societies with the A. A. A. S., in inviting the International Congress to hold the session next after that of London, in the United States. This committee has addressed a circular to a number of institutions, but owing to the lateness of the season when this was done it has only received favorable responses as yet from The University of Pennsylvania, The Academy of Natural Sciences, The University of California and the California Academy of Sciences.

A sub-committee was appointed to communicate with the Com mittee of Direction of the geological map of Europe, and to secu the addition of the United States to the list of "great countries to each of which 100 copies of the map were to be assigned at price per copy less than that at which they were to be sold to t public. This committee has performed its task and received a f vorable though as yet informal reply from the Committee of Dire tion, which only awaits the formal assent of the entire Committ to grant the request.

As a necessary consequence, a circular was addressed to a lar number of institutions of learning offering each the opportuni of subscribing for one or more of these hundred copies of the ma Eleven applications have been thus far received.

The American Committee requested Professor Hitchcock to col according to the system proposed by the Congress, the area select by Major Powell to test the efficiency of the various proposed col systems.

A second meeting of the committee was held in New York May 22, 1886. At this meeting Prof. H. S. Williams was elect treasurer of the committee; the secretary presented his report, whi was accepted, and made a statement of his account which was dited and pronounced correct. An assessment of $25.25, to p the expenses of the pamphlet, was made on each member of the co mittee and attention was called to the accounts of the Congre published by Professors Renevier and Choffat.

In conclusion, your Committee recommends to the American A sociation for the Advancement of Science that it authorize officers to sign the enclosed invitation which has already be signed by several of the large institutions of learning and origi research of the country, and is to be addressed to the Internatio Geological Congress.[1]

JAMES HALL,

J. W. DAWSON,	G. A. COOK,
J. S. NEWBERRY,	JOHN J. STEVENSON,
T. STERRY HUNT,	E. D. COPE,
C. H. HITCHCOCK,	E. A. SMITH,
RAPHAEL PUMPELLY,	H. S. WILLIAMS,
J. P. LESLEY,	N. H. WINCHELL,
J. W. POWELL,	PERSIFOR FRAZER.

[1] A copy of the pamphlet published by the Committee, and one of each of the cir lars referred to, accompanied the above report.

SECTION A.

MATHEMATICS AND ASTRONOMY.

ADDRESS

BY

J. WILLARD GIBBS,

VICE PRESIDENT, SECTION A, MATHEMATICS AND ASTRONOMY.

MULTIPLE ALGEBRA.

It has been said that "the human mind has never invented a labor-saving machine equal to algebra."[1] If this be true, it is but natural and proper that an age like our own, characterized by the multiplication of labor-saving machinery, should be distinguished by an unexampled development of this most refined and most beautiful of machines. That such has been the case, none will question. The improvement has been in every part. Even to enumerate the principal lines of advance would be a task for any one; for me an impossibility. But if we should ask, in what direction the advance has been made, which is to characterize the development of algebra in our day, we may, I think, point to that broadening of its field and methods, which gives us *multiple algebra.*

Of the importance of this change in the conception of the office of algebra, it is hardly necessary to speak: that it is really characteristic of our time will be most evident if we go back some two- or threescore years, to the time when the seeds were sown which are now yielding so abundant a harvest. The failure of Möbius, Hamilton, Grassmann, Saint-Venant to make an immediate impression upon the course of mathematical thought in any way commensurate with the importance of their discoveries is the most conspicuous evidence that the times were not ripe for the methods which they sought to introduce. A satisfactory theory of the imaginary quantities of ordinary algebra, which is essentially a simple case of multiple algebra, with difficulty obtained recogni-

[1] *The Nation*, Vol. XXXIII, p. 237.

tion in the first third of this century. We must observe that *double algebra*, as it has been called, was not sought for or inven
—it forced itself, unbidden, upon the attention of mathematic
and with its rules already formed.

But the idea of double algebra, once received, although
were unwillingly, must have suggested to many minds, mo
less distinctly, the possibility of other multiple algebras, of h
orders, possessing interesting or useful properties.

The application of double algebra to the geometry of the
suggested not unnaturally to Hamilton the idea of a triple al
which should be capable of a similar application to the geor
of three dimensions. He was unable to find a satisfactory
algebra, but discovered at length a quadruple algebra, *q
nions*, which answered his purpose, thus satisfying, as he sa
one of his letters, an intellectual want which had haunted h
least fifteen years. So confident was he of the value of this
bra, that the same hour he obtained permission to lay his di
ery before the Royal Irish Academy, which he did on Nove
13, 1843.[1] This system of multiple algebra is far better k
than any other, except the ordinary double algebra of imag
quantities,—far too well known to require any especial noti
my hands. All that here requires our attention is the close
torical connection between the imaginaries of ordinary al
and Hamilton's system, a fact emphasized by Hamilton hi
and most writers on quaternions. It was quite otherwise
Möbius and Grassmann.

The point of departure of the *Barycentrischer Calcul* of Mö
published in 1827,—a work of which Clebsch has said that i
never be admired enough,[2]— is the use of equations in whicl
terms consist of letters representing points with numerical c
cients, to express barycentric relations between the points.
that the point S is the centre of gravity of weights, a, b,
placed at the points A, B, C, D, respectively, is expresse
the equation

$$(a+b+c+d)S = aA + bB + cC + dD.$$

An equation of the more general form

$$aA + bB + cC + \text{etc.}, = pP + qQ + rR + \text{etc.}$$

[1] *Phil. Mag.* (3), Vol. XXV, p. 490; *North British Review*, Vol. XLV (1866), p.
[2] See his eulogy on Plücker, p. 14, *Gött. Abhandl.*, Vol. XVI.

signifies that the weights a, b, c, etc., at the points A, B, C, etc., have the same sum and the same centre of gravity as the weights p, q, r, etc., at the points P, Q, R, etc., or, in other words, that the former are barycentrically equivalent to the latter. Such equations, of which each represents four ordinary equations, may evidently be multiplied or divided by scalars,[1] may be added or subtracted, and may have their terms arranged and transposed, exactly like the ordinary equations of algebra. It follows that the elimination of letters representing points from equations of this kind is performed by the rules of ordinary algebra. This is evidently the beginning of a quadruple algebra, and is identical, as far as it goes, with Grassmann's marvellous geometrical algebra.

In the same work we find, also, for the first time, so far as I am aware, the distinction of positive and negative consistently carried out on the designation of segments of lines, of triangles and of tetrahedra, viz., that a change in place of two letters, in such expressions as AB, ABC, $ABCD$, is equivalent to prefixing the negative sign. It is impossible to overestimate the importance of this step, which gives to designations of this kind the generality and precision of algebra.

Moreover, if A, B, C are three points in the same straight line, and D any point outside of that line, the author observes that we have

$$AB + BC + CA = 0,$$

and, also, with D prefixed,

$$DAB + DBC + DCA = 0.$$

Again, if A, B, C, D are four points in the same plane, and E any point outside of that plane, we have

$$ABC - BCD + CDA - DAB = 0,$$

and also, with E prefixed,

$$EABC - EBCD + ECDA - EDAB = 0.$$

The similarity to multiplication in the derivation of these formulæ cannot have escaped the author's notice. Yet he does not seem to have been able to generalize these processes. It was re-

[1] I use this term in Hamilton's sense, to denote the ordinary positive and negative quantities of algebra. It may, however, be observed that in most cases in which I shall have occasion to use it, the proposition would hold without exclusion of imaginary quantities,—that this exclusion is generally for simplicity and not from necessity.

served for the genius of Grassmann to see that AB might be garded as the product of A and B, DAB as the product of D a AB, and $EABC$ as the product of E and ABC. That Möb could not make this step was evidently due to the fact that had not the conception of the addition of other multiple qu tities than such as may be represented by masses situated points. Even the addition of vectors (*i. e.*, the fact that composition of directed lines could be treated as an additio seems to have been unknown to him at this time, although subsequently discovered it, and used it in his *Mechanik des Hi mels*, which was published in 1843. This addition of vectors, *geometrical addition*, seems to have occurred independently many persons.

Seventeen years after the *Barycentrischer Calcul*, in 1844, the y in which Hamilton's first papers on quaternions appeared in pri Grassmann published his *Lineale Ausdehnungslehre*, in which developed the idea and the properties of the *external* or *combi torial product*, a conception which is perhaps to be regarded as greatest monument of the author's genius. This volume was have been followed by another, of the nature of which some intir tion was given in the preface and in the work itself. We are pecially told that the *internal product*,[1] which for vectors is identi except in sign with the scalar part of Hamilton's product (just Grassman's external product of two vectors is practically identi with the vector part of Hamilton's product), and the *open produ* which in the language of to-day would be called a matrix, were be treated in the second volume. But both the internal prod of vectors and the open product are clearly defined, and their fu damental properties indicated, in this first volume.

This remarkable work remained unnoticed for more than twer years, a fact which was doubtless due in part to the very abstra and philosophical manner in which the subject was presented. consequence of this neglect, the author changed his plan, and stead of a supplementary volume, published in 1862 a single vo ume entitled *Ausdehnungslehre*, in which were treated, in an e tirely different style, the same topics as in the first volume, as we as those which he had reserved for the second.

Deferring for the moment the discussion of these topics in ord to follow the course of events, we find in the year following t

[1] See the preface. [2] See § 172.

first *Ausdehnungslehre* a remarkable memoir of Saint-Venant[1], in which are clearly described the addition both of vectors and of oriented areas, the differentiation of these with respect to a scalar quantity, and a multiplication of two vectors and of a vector and an oriented area. These multiplications, called by the author *geometrical*, are entirely identical with Grassmann's external multiplication of the same quantities.

It is a striking fact in the history of the subject, that the short period of less than two years was marked by the appearance of well-developed and valuable systems of multiple algebra by British, German, and French authors, working apparently entirely independently of one another. No system of multiple algebra had appeared before, so far as I know, except such as were confined to additive processes with multiplication by scalars, or related to the ordinary double algebra of imaginary quantities. But the appearance of a single one of these systems would have been sufficient to mark an epoch, perhaps the most important epoch in the history of the subject.

In 1853 and 1854, Cauchy published several memoirs on what he called *clefs algébriques*.[2] These were units subject generally to combinatorial multiplication. His principal application was to the theory of elimination. In this application, as in the law of multiplication, he had been anticipated by Grassmann.

We come next to Cayley's celebrated *Memoir on the Theory of Matrices*[3] in 1858, of which Sylvester has said that it seems to him to have ushered in the reign of Algebra the Second.[4] I quote this dictum of a master as showing his opinion of the importance of the subject and of the memoir. But the foundations of the theory of matrices, regarded as multiple quantities, seem to me to have been already laid in the *Ausdehnungslehre* of 1844. To Grassmann's treatment of this subject we shall recur later.

After the *Ausdehnungslehre* of 1862, already mentioned, we come to Hankel's *Vorlesungen über die complexen Zahlen*, 1867. Under this title the author treats of the imaginary quantities of ordinary algebra, of what he calls *alternirende Zahlen*, and of quaternions. These alternate numbers, like Cauchy's *clefs*, are quantities subject to Grassmann's law of combinatorial multiplication. This treatise, published twenty-three years after the

[1] *C. R.* Vol. XXI, p. 620. [2] *C. R.* Vols. XXXVI, ff. [3] *Phil. Trans.* Vol. CXLVIII.
[4] *Amer. Journ. Math.* Vol. VI, p. 271.

first *Ausdehnungslehre*, marks the first impression which we discover of Grassmann's ideas upon the course of mathema thought. The transcendent importance of these ideas was appreciated by the author, whose very able work seems to had considerable influence in calling the attention of mathe cians to the subject.

In 1870, Professor Benjamin Peirce published his *Linear ciative Algebra*, subsequently developed and enriched by his Professor C. S. Peirce. The fact that the edition was lithogra seems to indicate that even at this late date a work of this could only be regarded as addressed to a limited number of ers. But the increasing interest in such subjects is shown b republication of this memoir in 1881,[1] as by that of the first *dehnunsglehre* in 1878.

The article on quaternions which has just appeared in the *cyclopædia Brittanica* mentions twelve treatises, including se editions and translations, besides the original treatises of H ton. That all the twelve are later than 1861 and all but two than 1872 shows the rapid increase of interest in this subject i last years.

Finally, we arrive at the *Lectures on the Principles of Uni Algebra* by the distinguished foreigner whose sojourn amor has given such an impulse to mathematical study in this cou The publication of these lectures, commenced in 1884 in the *A ican Journal of Mathematics*, has not as yet been complet a want but imperfectly supplied by the author's somewhat d tory publication of many remarkable papers on the same su (which might be more definitely expressed as the algebra of trices) in various foreign journals.

It is not an accident that this century has seen the rise of m ple algebra. The course of the development of ideas in al and in geometry, although in the main independent of an from this source, has nevertheless to a very large extent be a character which can only find its natural expression in mu algebra.

Our Modern Higher Algebra is especially occupied wit theory of linear transformations. Now what are the first no which we meet in this theory? We have a set of n variables

[1] *Amer. Journ. Math.*, Vol. IV.

x, y, z, and another set, say x', y', z', which are homogeneous linear functions of the first, and therefore expressible in terms of them by means of a block of n^2 coëfficients. Here the quantities occur by sets, and invite the notations of multiple algebra. It was in fact shown by Grassmann in his first *Ausdehnungslehre* and by Cauchy nine years later, that the notations of multiple algebra afford a natural key to the subject of elimination.

Now I do not merely mean that we may save a little time or space by writing perhaps ρ for x, y and z; ρ' for x', y' and z'; and Φ for a block of n^2 quantities. But I mean that the subject as usually treated under the title of determinants has a stunted and misdirected development on account of the limitations of single algebra. This will appear from a very simple illustration. After a little preliminary matter, the student comes generally to a chapter entitled "Multiplication of Determinants," in which he is taught that the product of the determinants of two matrices may be found by performing a somewhat lengthy operation on the two matrices, by which he obtains a third matrix, and then taking the determinant of this. But what significance, what value has this theorem? For aught that appears in the majority of treatises which I have seen, we have only a complicated and lengthy way of performing a simple operation. The real facts of the case may be stated as follows:

Suppose the set of n quantities ρ' to be derived from the set ρ by the matrix Φ, which we may express by

$$\rho' = \Phi . \rho;$$

and suppose the set ρ'' to be derived from the set ρ' by the matrix Ψ, *i. e.*,

$$\rho'' = \Psi . \rho',$$

and

$$\rho'' = \Psi . \Phi . \rho;$$

it is evident that ρ'' can be derived from ρ by the operation of a single matrix, say Θ, *i. e.*,

$$\rho'' = \Theta . \rho,$$

so that

$$\Theta = \Psi . \Phi .$$

In the language of multiple algebra Θ is called the product of Ψ and Φ. It is of course interesting to see how it is derived from the latter, and it is little more than a schoolboy's exercise to determine this. Now this matrix Θ has the property that its determinant is equal to the products of the determinants of Ψ and Φ. And this property is all that is generally stated in the books, and

the fundamental property, which is all that gives the subje
interest, that θ is itself the product of Ψ and Φ in the langua
multiple algebra, *i. e.*, that operating by θ is equivalent to c
ting successively by Φ and Ψ, is generally omitted. The cl
on this subject, in most treatises which I have seen, reads ver
the play of Hamlet with Hamlet's part left out.

And what is the cause of this omission? Certainly not
rance of the property in question. The fact that it is occasio
given would be a sufficient bar to this answer. It is becaus
author fails to see that his real subject is matrices and not det
nants. Of course, in a certain sense, the author has a rig
choose his subject. But this does not mean that the choice
important, or that it should be determined by chance or by ca
The problem well put is half solved, as we all know. If one ch
the subject ill, it will develop itself in a cramped manner.

But the case is really much worse than I have stated it.
only is the true significance of the formation of θ from Ψ and
given, but the student is often not taught to form the m
which is the product of Ψ and Φ, but one which is the product o
of these matrices and the conjugate of the other. Thus the
osition which is proved loses all its simplicity and signific
and must be recast before the instructor can explain its true
ings to the student. This fault has been denounced by Sylv
and if anyone thinks I make too much of the standpoint from
the subject is viewed, I will refer him to the opening parag
of the "Lectures on Universal Algebra" in the sixth volume c
American Journal of Mathematics, where, with a wealth of illu
tion and an energy of diction which I cannot emulate, the
eloquent of mathematicians expresses his sense of the import
of the substitution of the idea of the matrix for that of the d
minant. If then so important, why was the idea of the matri
slip? Of course the writers on this subject had it to comm
with. One cannot even define a determinant without the id
a matrix. The simple fact is that in general the writers on
subject have especially developed those ideas, which are natu
expressed in simple algebra, and have postponed or slurred
or omitted altogether those ideas which find their natural ex
sion in multiple algebra. But in this subject the latter ha
to be the fundamental ideas, and those which ought to direc
whole course of thought.

I have taken a very simple illustration, perhaps the very

theorem which meets the student after those immediately connected with the introductory definitions, both because the simplest illustration is really the best, and because I am here most at home. But the principles of multiple algebra seem to me to shed a flood of light into every corner of the subjects usually treated under the title of determinants, the subject gaining as much in breadth from the new notions as in simplicity from the new notations; and in the more intricate subjects of invariants, covariants, etc., I believe that the principles of multiple algebra are ready to perform an equal service. Certainly they make many things seem very simple to me, which I should otherwise find difficult of comprehension.

Let us turn to geometry.

If we were asked to characterize in a single word our modern geometry, we would perhaps say that it is a geometry of position. Now position is essentially a multiple quantity, or if you prefer, is naturally represented in algebra by a multiple quantity. And the growth in this century of the so-called synthetic as opposed to analytical geometry seems due to the fact that by the ordinary analysis geometers could not easily express, except in a cumbersome and unnatural manner, the sort of relations in which they were particularly interested. With the introduction of the notations of multiple algebra, this difficulty falls away, and with it the opposition between synthetic and analytical geometry.

It is, however, interesting and very instructive to observe how the ingenuity of mathematicians has often triumphed over the limitations of ordinary algebra. A conspicuous example and one of the simplest is seen in the *Mécanique Analytique*, where the author, by the use of what are sometimes called indeterminate equations, is able to write in one equation the equivalent of an indefinite number. Thus the equation

$$X\,dx + Y\,dy + Z\,dz = 0,$$

by the indeterminateness of the values of dx, dy, dz, is made equivalent to the three equations

$$X = 0, \qquad Y = 0, \qquad Z = 0.$$

It is instructive to compare this with

$$Xi + Yj + Zk = 0,$$

which is the form that Hamilton or Grassmann would have used.

The use of this analytical artifice, if such it can be called, ru
through the work and is fairly characteristic of it.

Again, the introduction of the potential in the theory of gr
or electricity, or magnetism, gives us a scalar quantity inste
a vector as the subject of study; and in mechanics generall
use of the force-function substitutes a simple quantity for a
plex. This method is in reality not different from that just
tioned, since Lagrange's indeterminate equation expresses, at
in its origin, the variation of the force-function. It is indee
real beauty of Lagrange's method that it is not so much an a
ical artifice, as the natural development of the subject.

In modern analytical geometry we find methods in use whic
exceedingly ingenious, and give forms curiously like those of
tiple algebra, but which, at least if logically carried out ver
are excessively artificial, and that for the expression of th
plest things. The simplest conceptions of the geometry of thr
mensions are points and planes, and the simplest relation be
these is that a point lies in a plane. Let us see how these n
have been handled by means of ordinary algebra, and by mu
algebra. It will illustrate the characteristic difference o
methods, perhaps as well as the reading of an elaborate trea

In multiple algebra a point is designated by a single lette
as it is in what is called synthetic geometry, and as it gener
by the ordinary analyst, when he is not writing equations. I
his equations, instead of a single letter the analyst introduce
eral letters (coördinates) to represent the point.

A plane may be represented in multiple algebra as in syn
geometry by a single letter; in the ordinary algebra it is
times represented by three coördinates, for which it is most
venient to take the reciprocals of the segments cut off by the
on three axes. But the modern analyst has a more ingenious m
of representing the plane. He observes that the equation o
plane may be written

$$\xi x + \eta y + \zeta z = 1,$$

where ξ, η, ζ are the reciprocals of the segments, and x, y,
the coördinates of any point in the plane. Now if we set

$$p = \xi x + \eta y + \zeta z,$$

this letter will represent an expression which represents the
In fact, we may say that p implicitly contains ξ, η, and ζ, whi

the coördinates of the plane. We may therefore speak of the plane p, and for many purposes can introduce the letter p into our equations instead of ξ, η, ζ. For example, the equation

$$p''' = \frac{p' + p''}{2} \tag{3}$$

is equivalent to the three equations

$$\xi''' = \frac{\xi' + \xi''}{2}, \qquad \eta''' = \frac{\eta' + \eta''}{2}, \qquad \zeta''' = \frac{\zeta' + \zeta''}{2}. \tag{4}$$

It is to be noticed that on account of the indeterminateness of the x, y, and z, this method, regarded as an analytical artifice, is identical with that of Lagrange, also that in multiple algebra we should have an equation of precisely the same form as (3) to express the same relation between the planes, but that the equation would be explained to the student in a totally different manner. This we shall see more particularly hereafter.

It is curious that we have thus a simpler notation for a plane than for a point. This however may be reversed. If we commence with the notion of the coördinates of a plane, ξ, η, ζ, the equation of a point (*i. e.*, the equation between ξ, η, ζ which will hold for every plane passing through the point) will be

$$x\xi + y\eta + z\zeta = 1, \tag{5}$$

where x, y, z are the coördinates of the point. Now if we set

$$q = x\xi + y\eta + z\zeta, \tag{6}$$

we may regard the single letter q as representing the point, and use it, in many cases, instead of the coördinates x, y, z, which indeed it implicitly contains. Thus we may write

$$q''' = \frac{q' + q''}{2} \tag{7}$$

for the three equations

$$x''' = \frac{x' + x''}{2}, \qquad y''' = \frac{y' + y''}{2}, \qquad z''' = \frac{z' + z''}{2}. \tag{8}$$

Here, by an analytical artifice, we come to equations identical in form and meaning to those used by Hamilton, Grassmann, and even by Möbius in 1827. But the explanations of the formulæ would differ widely. The methods of the founders of multiple algebra are characterized by a bold simplicity, that of the modern geometry by a somewhat bewildering ingenuity. That p and q represent the same expression (in one case x, y, z, and in the other ξ, η, ζ being indeterminate) is a circumstance which may easily become perplexing. I am not quite certain that it would be convenient

to use both of these abridged notations at the same time. In
if the geometer using these methods were asked to express b
equation in p and q that the point q lies in the plane p, he n
find himself somewhat entangled in the meshes of his own
nuity, and need some new artifice to extricate himself. I d
mean that his genius might not possibly be equal to the occa
but I do mean very seriously that it is a vicious method w
requires any ingenuity or any artifice to express so simple a
tion.

If we use the methods of multiple algebra which are most
parable to those just described, a point is naturally represent
a vector (ρ) drawn to it from the origin, a plane by a vecto
drawn from the origin perpendicularly toward the plane an
length equal to the reciprocal of the distance of the plane fro
origin. The equation

$$\sigma''' = \frac{\sigma' + \sigma''}{2}$$

will have precisely the same meaning as equation (3), and

$$\rho''' = \frac{\rho' + \rho''}{2}$$

will have precisely the same meaning as equation (7), viz.,
the point ρ''' is in the middle between ρ' and ρ''. That the po
lies in the plane σ is expressed by equating to unity the pro
of ρ and σ called by Grassmann internal, or by Hamilton c
the scalar part of the product taken negatively. By wha
name called, the quantity in question is the product of the le
of the vectors and the cosine of the included angle. It is of c
immaterial what particular sign we use to express this produ
whether we write

$$\rho.\sigma = 1, \qquad \text{or} \qquad S\rho\sigma = -1.$$

I should myself prefer the simplest possible sign for so sim
relation. It may be observed that ρ and σ may be express
the geometrical sum of their components parallel to a set of
pendicular axes, viz.,

$$\rho = xi + yj + zk, \qquad \sigma = \xi i + \eta j + \zeta k.$$

By substitution of these values, equation (11) becomes by the
of this kind of multiplication

$$x\xi + y\eta + z\zeta = 1.$$

My object in going over these elementary matters is to ca
tention to the very roundabout way in which the ordinary an

makes out to represent a point or a plane by a single letter, as distinguished from the directness and simplicity of the notations of multiple algebra, and also to the fact that the representations of points and planes by single letters in the ordinary analysis are not, when obtained, as amenable to analytical treatment as are the notations of multiple algebra.

I have compared that form of the ordinary analysis which relates to Cartesian axes with a vector analysis. But the case is essentially the same, if we compare the form of ordinary analysis which relates to a fundamental tetrahedron with Grassmann's geometrical analysis, founded on the point as the elementary quantity.

In the method of ordinary analysis, a point is represented by four coördinates, of which each represents the distance of the point from a plane of the tetrahedron divided by the distance of the opposite vertex from the same plane. The equation of a plane may be put in the form

$$\xi x + \eta y + \zeta z + \omega w = 0, \tag{14}$$

where ξ, η, ζ, ω are the distances of the plane from the four points, and x, y, z, w are the coördinates of any point in the plane. Here we may set

$$p = \xi x + \eta y + \zeta z + \omega w, \tag{15}$$

and say that p represents the plane. To some extent we can introduce this letter into equations instead of ξ, η, ζ, ω. Thus the equation

$$l p' + m p'' + n p''' = 0 \tag{16}$$

(which denotes that the planes p', p'', p''', meet in a common line, making angles of which the sines are proportional to l, m, and n) is equivalent to the four equations

$$l \xi' + m \xi'' + n \xi''' = 0, \qquad l \eta' + m \eta'' + n \eta''' = 0, \text{ etc.} \tag{17}$$

Again, we may regard ξ, η, ζ, ω as the coördinates of a plane. The equation of a point will then be

$$x \xi + y \eta + z \zeta + w \omega = 0. \tag{18}$$

If we set

$$q = x \xi + y \eta + z \zeta + w \omega, \tag{19}$$

we may say that q represents the point. The equation

$$q''' = \frac{q' + q''}{2}, \tag{20}$$

which indicates that the point q''' bisects the line between q' and q'', is equivalent to the four equations

$$\xi' = \frac{\xi'' + \xi'''}{2}, \qquad \eta' = \frac{\eta'' + \eta'''}{2}, \text{ etc.}$$

To express that the point q lies in the plane p does not
easy, without going back to the use of coördinates.

The form of multiple algebra which is to be compared to tl
the geometrical algebra of Möbius and Grassmann, in which p
without reference to any origin are represented by single le
say by Italic capitals, and planes may also be represente
single letters, say by Greek capitals. An equation like

$$Q''' = \frac{Q' + Q''}{2},$$

has exactly the same meaning as equation (20) of ordinary
bra. So

$$l\,\Pi' + m\,\Pi'' + n\,\Pi''' = 0$$

has precisely the same meaning as equation (16) of ordinary
bra. That the point Q lies in the plane Π is expressed by equ
to zero the product of Q and Π which is called by Grassmann e
nal and which might be defined as the distance of the point
the plane. We may write this

$$Q \times \Pi = 0.$$

To show that so simple an expression is really amenable to an
ical treatment, I observe that Q may be expressed in terms o
four points (not in the same plane) on the barycentric prin
explained above, viz.,

$$Q = x\,A + y\,B + z\,C + w\,D,$$

and Π may be expressed in terms of combinatorial products
B, C, and D, viz.,

$$\Pi = \xi\,B \times C \times D + \eta\,C \times A \times D + \zeta\,D \times A \times B + \omega A \times C \times B.$$

and by these substitutions, by the laws of the combinatorial pr
to be mentioned hereafter, equation (24) is transformed into

$$w\,\omega + x\,\xi + y\,\eta + z\,\zeta = 0,$$

which is identical with the formula of ordinary analysis.[1]

I have gone at length into this very simple point, in order
lustrate the fact which I think is a general one, that the m
geometry is not only tending to results which are appropr
expressed in multiple algebra, but that it is actually strivi

[1]The letters ξ, η, ζ, ω, here denote the distances of the plane Π from the point
C, D, divided by six times the volume of the tetrahedron A, B, C, D. The lett
z, w, denote the tetrahedral coördinates as above.

clothe itself in forms which are remarkably similar to the notations of multiple algebra, only less simple and general, and far less amenable to analytical treatment, and therefore, that a certain logical necessity calls for throwing off the yoke under which analytical geometry has so long labored. And lest this should seem to be the utterance of an uninformed enthusiasm, or the echoing of the possibly exaggerated claims of the devotees of a particular branch of mathematical study, I will quote a sentence from Clebsch and from Clifford, relating to the past and to the future of multiple algebra. The former in his eulogy on Plücker,[1] in 1871, speaking of recent advances in geometry, says that "in a certain sense the coördinates of a straight line, and in general a great part of the fundamental conceptions of the newer algebra, are contained in the *Ausdehnungslehre* of 1844," and Clifford[2] in the last year of his life, speaking of the *Ausdehnungslehre*, with which he had but recently become acquainted, expresses "his profound admiration of that extraordinary work, and his conviction that its principles will exercise a vast influence upon the future of mathematical science."

Another subject in which we find a tendency toward the forms and methods of multiple algebra, is the calculus of operations. Our ordinary analysis introduces operators; and the successive operations A and B may be equivalent to the operation C. To express this in an equation we may write

$$B\,A\,(x) = C\,(x),$$

where x is any quantity or function. We may also have occasion to write

$$A\,(x) + B\,(x) = D\,(x), \qquad \text{or} \qquad (A + B)\,(x) = D\,(x).$$

But it is almost impossible to resist the tendency to express these relations in the form

$$B\,A = C,$$
$$A + B = D,$$

in which the operators appear in a sense as quantities, *i. e.*, as subjects of functional operation. Now since these operators are often of such nature that they cannot be perfectly specified by a single numerical quantity, when we treat them as quantities they must be regarded as multiple quantities. In this way certain formulæ which essentially belong to multiple algebra get a precarious footing where they are only allowed because they are regarded as

[1] *Gött. Abhandl.* Vol. 16, p. 28. [2] *Amer. Journ. Math.*, Vol. I, p. 350.

abridged notations for equations in ordinary algebra. Yet t
logical development of such notations would lead a good way
multiple algebra, and doubtless many investigators have enter
the field from this side.

One might also notice, to show how the ordinary algebra is b
coming saturated with the notions and notations which seem d
tined to turn it into a multiple algebra, the notation so comm
in the higher algebra

$$(a, b, c \between x, y, z)$$

for

$$a x + b y + c z.$$

This is evidently the same as Grassmann's internal product of t
multiple quantities (a, b, c) and (x, y, z), or, in the language
quaternions, the scalar part, taken negatively, of the product
the vectors of which a, b, c and x, y, z are the components.
similar correspondence with Grassmann's methods might, I thin
be shown in such notations as, for example,

$$(a, b, c, d, \between x, y)^3.$$

The free admission of such notations is doubtless due to the fa
that they are regarded simply as abridged notations.

The author of the celebrated "Memoir on the Theory of Matrice
goes much farther than this in his use of the forms of multiple
gebra. Thus he writes explicitly one equation to stand for sever
without the use of any of the analytical artifices which have be
mentioned. This work has indeed, as we have seen, been chara
terized as marking the commencement of multiple algebra,—
view to which we can only take exception as not doing justice
earlier writers.

But the significance of this memoir with regard to the poi
which I am now considering is that it shows that the chasm
marked in the second quarter of this century is destined to
closed up. Notions and notations for which a Cayley is spons
will not be excluded from good society among mathematician
And if we admit as suitable the notations used in this memo
(where it is noticeable that the author rather avoids multiple
gebra, and only uses it very sparingly), we shall logically be broug
to use a great deal more. For example, if it is a good thing
write in our equations a single letter to represent a matrix of
numerical quantities, why not use a single letter to represent t
n quantities operated upon, as Grassmann and Hamilton have don

Logical consistency seems to demand it. And if we may use the sign χ to denote an operation by which two sets of quantities are combined to form a third set, as is the case in this memoir, why not use other signs to denote other functional operations of which the result is a multiple quantity? If it be conceded that this is the proper method to follow where simplicity of conception, or brevity of expression, or ease of transformation is served thereby, our algebra will become in large part a multiple algebra.

We have considered the subject a good while from the outside; we have glanced at the principal events in the history of multiple algebra; we have seen how the course of modern thought seems to demand its aid, how it is actually leaning toward it, and beginning to adopt its methods. It may be worth while to direct our attention more critically to multiple algebra itself, and inquire into its essential character and its most important principles.

I do not know that anything useful or interesting, which relates to multiple quantity, and can be symbolically expressed, falls outside of the domain of multiple algebra. But if it is asked, what notions are to be regarded as fundamental, we must answer, here as elsewhere, those which are most simple and fruitful. Unquestionably, no relations are more so, than those which are known by the names of addition and multiplication.

Perhaps I should here notice the essentially different manner in which the multiplication of multiple quantities has been viewed by different writers. Some, as Hamilton, or De Morgan, or Peirce, speak of the product of two multiple quantities, as if only one product could exist, at least in the same algebra. Others, as Grassmann, speak of various kinds of products for the same multiple quantities. Thus Hamilton seems for many years to have agitated the question, what he should regard as the product of each pair of a set of triplets, or in the geometrical application of the subject, what he should regard as the product of each pair of a system of perpendicular directed lines.[1] Grassmann asks, What products, *i. e.*, what distributive functions of the multiple quantities are most important?

It may be that in some cases the fact that only one kind of product is known in ordinary algebra has led those to whom the problem presented itself in the form of finding a new algebra to adopt this characteristic derived from the old. Perhaps the reason lies

[1] *Phil. Mag.*, (3), XXV, p. 490; *North British Review*, XLV (1866), p. 57.

deeper in a distinction like that in arithmetic between con
and abstract numbers or quantities. The multiple quantitie
responding to concrete quantities such as ten apples or three n
are evidently such combinations as ten apples + seven ora
three miles northward + five miles eastward, or six miles
direction fifty degrees east of north. Such are the fundam
multiple quantities from Grassmann's point of view. But i
ask what it is in multiple algebra which corresponds to an abs
number like twelve, which is essentially an operator, which ch
one mile into twelve miles, and $1,000 into $12,000, the most
eral answer would evidently be, an operator which will work
changes as, for example, that of ten apples + seven oranges
fifty apples + 100 oranges, or that of one vector into anothe

Now an operator has, of course, one characteristic relation,
its relation to the operand. This needs no especial defin
since it is contained in the definition of the operator. If th
eration is distributive, it may not inappropriately be called n
plication, and the result is *par excellence* the product of the ope
and operand. The sum of operators *quâ* operators, is an ope
which gives for the product the sum of the products given by th
erators to be added. The product of two operators is an ope
which is equivalent to the successive operations of the fac
This multiplication is necessarily associative, and its definiti
not really different from that of the operators themselves.
here I may observe that Professor C. S. Peirce has shown
his father's associative algebras may be regarded as operat
and matricular.[1]

Now, the calculus of distributive operators is a subject of
extent and importance, but Grassmann's view is the more co
hensive, since it embraces the other with something besides.
every quantitative operator may be regarded as a quantity,
as the subject of mathematical operation, but every quantity
not be regarded as an operator; precisely as in grammar
verb may be taken as substantive, as in the infinitive, while
substantive does not give us a verb.

Grassmann's view seems also the most practical and conve
For we often use many functions of the same pair of mu
quantities, which are distributive with respect to both, an
need some simple designation to indicate a property of such
damental importance in the algebra of such functions, and n

[1] *Amer. Journ. Math.*, Vol. IV, p. 221.

vantage appears in singling out a particular function to be alone called the product. Even in quaternions, where Hamilton speaks of only one product of two vectors (regarding it as a special case of the product of quaternions, *i. e.*, of operators), he nevertheless comes to use the scalar part of this product and the vector part separately. Now the distributive law is satisfied by each of these, which, therefore, may conveniently be called products. In this sense we have three kinds of products of vectors in Hamilton's analysis.

Let us then adopt the more general view of multiplication, and call any function of two or more multiple quantities, which is distributive with respect to all, a product, with only this limitation, that when one of the factors is simply an ordinary algebraic quantity, its effect is to be taken in the ordinary sense.

It is to be observed that this definition of multiplication implies that we have an addition both of the kind of quantity to which the product belongs, and of the kinds to which the factors belong. Of course, these must be subject to the general formal laws of addition. I do not know that it is necessary for the purposes of a general discussion to stop to define these operations more particularly, either on their own account or to complete the definition of multiplication. Algebra, as a formal science, may rest on a purely formal foundation. To take our illustration again from mechanics, we may say that if a man is inventing a particular machine,—a sewing machine,—a reaper,—nothing is more important than that he should have a precise idea of the operation which his machine is to perform, yet when he is treating the general principles of mechanics he may discuss the lever, or the form of the teeth of wheels which will transmit uniform motion, without inquiring the purpose to which the apparatus is to be applied; and in like manner that if we were forming a particular algebra,—a geometrical algebra,—a mechanical algebra,—an algebra for the theory of elimination and substitution,—an algebra for the study of quantics,—we should commence by asking, What are the multiple quantities, or sets of quantities, which we have to consider? What are the additive relations between them? What are the multiplicative relations between them? etc., forming a perfectly defined and complete idea of these relations as we go along; but in the development of a general algebra no such definiteness of conception is requisite. Given only the purely formal law of the distributive character of multiplication,—this is sufficient for the

foundation of a science. Nor will such a science be merely a
time for an ingenious mind. It will serve a thousand purpos
the formation of particular algebras. Perhaps we shall find
in the most important cases, the particular algebra is little
than an application or interpretation of the general.

Grassmann observes that any kind of multiplication of n
quantities is characterized by the relations which hold bet
the products of n independent units. In certain kinds of mul
cation these characteristic relations will hold true of the proc
of any of the quantities.

Thus if the value of a product is independent of the order c
factors when these belong to the system of units, it will al
be independent of the order of the factors. The kind of mul
cation characterized by this relation and no other betweer
products is called by Grassmann *algebraic*, because its rules
cide with those of ordinary algebra. It is to be observed, how
that it gives rise to multiple quantities of higher orders. If n
pendent units are required to express the original quantities,
units will be required for the products of two factors, $n\frac{(n+1}{2}$
for the products of three factors, etc.

Again, if the value of a product of factors belonging to a sy
of units is multiplied by —1 when two factors change places
same will be true of the product of any factors obtained by
tion of the units. The kind of multiplication characterize
this relation and no other is called by Grassmann *external* or
binatorial. For our present purpose we may denote it by the
$\times$. It gives rise to multiple quantities of higher orders,
units being required to express the products of two fac
$n\frac{(n-1)(n-2)}{2 . 3}$ units for products of three factors, etc. All proc
of more than n factors are zero. The products of n factors
be expressed by a single unit, viz., the product of the n ori
units taken in a specified order, which is generally set equal
The products of n—1 factors are expressed in terms of n units,
of n—2 factors in terms of $n\frac{n-1}{2}$ units, etc. This kind of mul
cation is associative, like the algebraic.

Grassmann observes, with respect to binary products, that
two kinds of multiplication are the only kinds characterize
laws which are the same for any factors as for particular unit
cept indeed that characterized by no special laws, and tha
which all products are zero.[1] The last we may evidently rej

[1] Crelle's *Journ. f. Math.*, Vol. XLIX, p. 138.

nugatory. That for which there are no special laws, *i. e.*, in which no equations subsist between the products of a system of independent units, is also rejected by Grassmann, as not appearing to afford important applications. I shall, however, have occasion to speak of it, and shall call it the indeterminate product. In this kind of multiplication, n^2 units are required to express the products of two factors, and n^3 units for products of three factors, etc. It evidently may be regarded as associative.

Another very important kind of multiplication is that called by Grassmann *internal*. In the form in which I shall give it, which is less general than Grassmann's, it is in one respect the most simple of all, since its only result is a numerical quantity. It is essentially binary and characterized by laws of the form

$$i \,.\, i = 1, \qquad j \,.\, j = 1, \qquad k \,.\, k = 1, \text{ etc.,}$$
$$i \,.\, j = 0, \qquad j \,.\, i = 0, \qquad \text{etc.,}$$

where i, j, k, etc., represent a system of independent units. I use the dot as significant of this kind of multiplication.

Grassmann derives this kind of multiplication from the combinatorial by the following process. He defines the complement (Ergänzung) of a unit as the combinatorial product of all the other units, taken with such a sign that the combinatorial product of the unit and its complement shall be positive. The combinatorial product of a unit and its complement is therefore unity, and that of a unit and the complement of any other unit is zero. The internal product of two units is the combinatorial product of the first and the complement of the second.

It is important to observe that any scalar product of two factors of the same kind of multiple quantities, which is positive when the factors are identical, may be regarded as an internal product, *i. e.*, we may always find such a system of units, that the characteristic equations of the product will reduce to the above form. The nature of the subject may afford a definition of the product independent of any reference to a system of units. Such a definition will then have obvious advantages. An important case of this kind occurs in geometry in that product of two vectors which is obtained by multiplying the products of their lengths by the cosine of the angle which they include. This is an internal product in Grassmann's sense.

Let us now return to the indeterminate product, which I am inclined to regard as the most important of all, since we may derive from it the algebraic and the combinatorial. For this end,

we will prefix Σ to an indeterminate product to denote the sum all the terms obtained by taking the factors in every possible der. Then,

$$\Sigma \alpha \mid \beta \mid \gamma,$$

for instance, where the vertical line is used to denote the inde minate product,[1] is a distributive function of α, β and γ. I evidently not affected by changing the order of the letters. is, therefore, an algebraic product in the sense in which the t has been defined.

So, again, if we prefix $\Sigma \pm$ to an indeterminate product to note the sum of all terms obtained by giving the factors e possible order, those terms being taken negatively which are tained by an odd number of simple permutations,

$$\Sigma \pm \alpha \mid \beta \mid \gamma,$$

for instance, will be a distributive function of α, β, γ, whic multiplied by -1 when two of these letters change places. will therefore be a combinatorial product.

It is a characteristic and very important property of an i terminate product that every product of all its factors with other quantities is also a product of the indeterminate product the other quantities. We need not stop for a formal proof of proposition, which indeed is an immediate consequence of definitions of the terms.

These considerations bring us naturally to what Grassmann *regressive multiplication*, which I will first illustrate by a simple example. If n, the degree of multiplicity of our orig quantities, is 4, the combinatorial product of $\alpha \times \beta \times \gamma$ and δ viz.,

$$\alpha \times \beta \times \gamma \times \delta \times \varepsilon,$$

is necessarily zero, since the number of factors exceeds four. if for $\delta \times \varepsilon$ we set its equivalent

$$\delta \mid \varepsilon - \varepsilon \mid \delta,$$

we may multiply the first factor in each of these indetermi products combinatorially by $\alpha \times \beta \times \gamma$, and prefix the re which is a numerical quantity, as coëfficient to the second fa This will give

$$(\alpha \times \beta \times \gamma \times \delta)\, \varepsilon - (\alpha \times \beta \times \gamma \times \varepsilon)\, \delta.$$

[1] This notation must not be confounded with Grassmann's use of the vertical

Now, the first term of this expression is a product of $\alpha \times \beta \times \gamma$, δ, and ϵ, and therefore, by the principle just stated, a product of $\alpha \times \beta \times \gamma$ and $\delta \mid \epsilon$. The second term is a similar product of $\alpha \times \beta \times \gamma$ and $\epsilon \mid \delta$. Therefore the whole expression is a product of $\alpha \times \beta \times \gamma$ and $\delta \mid \epsilon - \epsilon \mid \delta$, that is, of $\alpha \times \beta \times \gamma$ and $\delta \times \epsilon$. This is, except in sign, what Grassmann calls the *regressive product* of $\alpha \times \beta \times \gamma$ and $\delta \times \epsilon$.

To generalize this process, we first observe that an expression of the form

$$\Sigma \pm \alpha \times \beta \mid \gamma \times \delta,$$

in which each term is an indeterminate product of two combinatorial products, and in which $\Sigma \pm$ denotes the sum of all terms obtained by putting every different pair of the letters before the dividing line, the negative sign being used for any terms which may be obtained by an odd number of simple permutations of the letters,— in other words, the expression

$$\alpha \times \beta \mid \gamma \times \delta - \alpha \times \gamma \mid \beta \times \delta - \alpha \times \delta \mid \gamma \times \beta + \beta \times \gamma \mid \alpha \times \delta$$
$$- \beta \times \delta \mid \alpha \times \gamma + \gamma \times \delta \mid \alpha \times \beta,$$

is a distributive function of α, β, γ, and δ, which is multiplied by -1 when two of these letters change places, and may, therefore, be regarded as equivalent to the combinatorial product $\alpha \times \beta \times \gamma \times \delta$. Now, if $n = 5$, the combinatorial product of

$$\rho \times \sigma \times \tau \qquad \text{and} \qquad \alpha \times \beta \times \gamma \times \delta$$

is zero. But if we multiply the first member of each of the above indeterminate products by $\rho \times \sigma \times \tau$, and prefix the result as coëfficient to the second member, we obtain

$$(\rho \times \sigma \times \tau \times \alpha \times \beta) \gamma \times \delta - (\rho \times \sigma \times \tau \times \alpha \times \gamma) \beta \times \delta + \text{etc.},$$

which is what Grassmann calls the regressive product of $\rho \times \sigma \times \tau$ and $\alpha \times \beta \times \gamma \times \delta$. It is easy to see that the principle may be extended so as to give a regressive product in any case in which the total number of factors of two combinatorial products is greater than n. Also, that we might form a regressive product by treating the first of the given combinatorials as we have treated the second. It may easily be shown that this would give the same result, except in some cases with a difference of sign. To avoid this inconvenience, we may make the rule, that whenever in the substitution of a sum of indeterminate products for a combinatorial, both factors of the indeterminate products are of odd degree, we

change the sign of the whole expression. With this underst
ing, the results which we obtain will be identical with G
mann's regressive product. The propriety of the name con
in the fact that the product is of less degree than either o
factors. For the contrary reason, the ordinary external or co
natorial multiplication is sometimes called by Grassmann
gressive.

Regressive multiplication is associative and exhibits a
remarkable analogy with the progressive. This analogy I
not time here to develop, but will only remark that in this ana
lies in its most general form that celebrated *principle of du*
which appears in various forms in geometry and certain bra
of analysis.

To fix our ideas, I may observe that in geometry the pro
sive multiplication of points gives successively lines, planes
volumes; the regressive multiplication of planes gives success
lines, points and scalar quantities.

The indeterminate product affords a natural key to the su
of matrices. In fact, a sum of indeterminate products of the
ond degree represents n^2 scalars, which constitute an ordina
quadratic matrix; a sum of indeterminate products of the
degree represents n^3 scalars, which constitute a cubic matrix,
I shall confine myself to the simplest and most important
that of quadratic matrices.

An expression of the form

$$\alpha\,(\lambda\,.\,\rho)$$

being a product of α, λ, and ρ, may be regarded as a produ
$\alpha \mid \lambda$ and ρ, by a principle already stated. Now if Φ deno
sum of indeterminate products, of second degree, say $\alpha \mid \lambda +$
$+$ etc., we may write

$$\Phi\,.\,\rho$$

for $$\alpha\,(\lambda\,.\,\rho) + \beta\,(\mu\,.\,\rho) + \text{etc.}$$

This is like ρ, a quantity of the first degree, and it is a hom
neous linear function of ρ. It is easy to see that the most ge
form of such a function may be expressed in this way. An
tion like

$$\sigma = \Phi\,.\,\rho$$

represents n equations in ordinary algebra, in which n variable
expressed as linear functions of n others by means of n^2
cients.

The internal product of two indeterminate products may be defined by the equation

$$(\alpha \mid \beta).(\gamma \mid \delta) = (\beta . \gamma)\, \alpha \mid \delta.$$

This defines the internal product of matrices, as

$$\Psi . \Phi.$$

This product evidently gives a matrix, the operation of which is equivalent to the successive operations of Φ and Ψ; *i. e.*,

$$(\Psi . \Phi) . \rho = \Psi . (\Phi . \rho).$$

We may express this a little more generally by saying that internal multiplication is associative when performed on a series of matrices, or on such a series terminated by a quantity of the first degree.

Another kind of multiplication of binary indeterminate products is that in which the preceding factors are multiplied combinatorially, and also the following. It may be defined by the equation

$$(\alpha \mid \lambda) \overset{\times}{\times} (\beta \mid \mu) \overset{\times}{\times} (\gamma \mid \nu) = \alpha \times \beta \times \gamma \mid \lambda \times \mu \times \nu.$$

This defines a multiplication of matrices denoted by the same symbol, as

$$\Phi \overset{\times}{\times} \Psi \overset{\times}{\times} \Omega, \qquad \Phi \overset{\times}{\times} \Psi \overset{\times}{\times} \Omega \overset{\times}{\times} \Theta.$$

This multiplication, which is associative and commutative, is of great importance in the theory of determinants. In fact,

$$\frac{1}{\underline{|n}}\, \Phi \overset{\times}{\times}{}^{n}$$

is the determinant of the matrix Φ. A lower power, as the m^{th}, with the divisor $n(n-1) \ldots (n-m+1)$ would express as multiple quantity all the subdeterminants of order m.[1]

It is evident that by the combination of the operations of indeterminate, algebraic, and combinatorial multiplication, we obtain multiple quantities of a more complicated nature than by the use of only one of these kinds of multiplication. The indeterminate product of combinatorial products we have already mentioned. The

[1] Quadratic matrices may also be represented by a sum of indeterminate products of a quantity of the first degree with a combinatorial product of $(n-1)$st degree, as, for example, when $n = 4$, by a sum of products of the form

$$\alpha \mid \beta \times \gamma \times \delta.$$

The theory of such matrices is almost identical with that of those of the other form, except that the external multiplication takes the place of the internal, in the multiplication of the matrices with each other and with quantities of the first degree.

combinatorial product of algebraic products, and the indete nate product of algebraic products, are also of great importa especially in the theory of quantics. These three multiplicati with the internal, especially in connection with the general p erty of the indeterminate product given above, and the deriva of the algebraic and combinatorial products from the indete nate, which affords a generalization of that property, give ris a great wealth of multiplicative relations between these mult quantities. I say "*wealth* of multiplicative relations" designedly there is hardly any kind of relations between things which are objects of mathematical study, which add so much to the resou of the student as those which we call multiplicative, except, haps the simpler class, which we call additive, and which are supposed in the multiplicative. This is a truth quite indepen of our using any of the notations of multiple algebra, althou suitable notation for such relations will of course increase value.

Perhaps, before closing, I ought to say a few words on the plications of multiple algebra.

First of all, geometry, and the geometrical sciences, which of things having position in space, kinematics, mechanics, ast omy, physics, crystallography, seem to demand a method of kind, for position in space is essentially a multiple quantity, can only be represented by simple quantities in an arbitrary cumbersome manner. For this reason, and because our spatia tuitions are more developed than those of any other class of m ematical relations, these subjects are especially adapted to troduce the student to the methods of multiple algebra. H Nature herself takes us by the hand, and leads us along by steps, as a mother teaches her child to walk. In the contempla of such subjects, Möbius, Hamilton, and Grassmann formed algebras, although the philosophical mind of the last was not isfied until he had produced a system unfettered by any sp relations. It is probably in connection with some of these subj that the notions of multiple algebra are most widely dissemina

Maxwell's *Treatise on Electricity and Magnetism* has don much to familiarize students of physics with quaternion notati that it seems impossible that this subject should ever again be tirely divorced from the methods of multiple algebra.

I wish that I could say as much of astronomy. It is, I th

to be regretted, that the oldest of the scientific applications of mathematics, the most dignified, the most conservative, should keep so far aloof from the youngest of mathematical methods; and standing as I do to-day, by some chance, among astronomers, although not of the guild, I cannot but endeavor to improve the opportunity by expressing my conviction of the advantages which astronomers might gain by employing some of the methods of multiple algebra. A very few of the fundamental notions of a vector analysis, the addition of vectors and what quaternionists would call the scalar part and the vector part of the product of two vectors (which may be defined without the notion of the quaternion), —these three notions with some four fundamental properties relating to them are sufficient to reduce enormously the labor of mastering such subjects as the elementary theory of orbits, the determination of an orbit from three observations, the differential equations which are used in determining the best orbit from an indefinite number of observations by the method of least squares, or those which give the perturbations when the elements are treated as variable. In all these subjects the analytical work is greatly simplified, and it is far easier to find the best form for numerical calculation than by the use of the ordinary analysis.

I may here remark that in its geometrical applications multiple algebra will naturally take one of two principal forms, according as vectors or points are taken as elementary quantities, *i. e.*, according as something having magnitude and direction, or something having magnitude and position at a point, is the fundamental conception. These forms of multiple algebra may be distinguished as *vector analysis* and *point analysis*. The former we may call a triple, the latter a quadruple algebra, if we determine the degree of the algebra from the degree of multiplicity of the fundamental conception. The former is included in the latter, since the subtraction of points gives us vectors, and in this way Grassmann's vector analysis is included in his point analysis. Hamilton's system, in which the vector is the fundamental idea, is nevetherless made a quadruple algebra by the addition of ordinary numerical quantities. For practical purposes, we may regard Hamilton's system as equivalent to Grassmann's algebra of vectors. Such practical equivalence is of course consistent with great differences of notation, and of the point of view from which the subject is regarded.

Perhaps I should add a word in regard to the nature of the prob-

lems which require a vector analysis, or the more general forr Grassmann's point analysis. The distinction of the problen very marked, and corresponds precisely to the distinction fam to all analysts between problems which are suitable for Carte coördinates, and those which are suitable for the use of tetr dral, or, in plane geometry, triangular coördinates. Thus mechanics, kinematics, astronomy, physics, or crystallogra Grassmann's point analysis will rarely be wanted. One m teach these subjects for years by a vector analysis, and never haps feel the need of any of the notions or notations which are culiar to the point analysis, precisely as in ordinary algebra might use the Cartesian coördinates in teaching these subj without any occasion for the use of tetrahedral coördinates. I t of one exception, which, however, confirms the rule. The important theory of forces acting on a rigid body is much b treated by point analysis than by vector analysis, exactly a ordinary algebra it is much better treated by tetrahedral coördi than by Cartesian,—I mean for the purpose of the elegant d opment of general propositions. A sufficient theory for the poses of numerical calculations can easily enough be give any method, and the most familiar to the student is for such tical purposes of course the best. On the other hand, the pr tive properties of bodies, the relations of collinearity, and si subjects, seem to demand the point analysis for their adeq treatment.

If I have said that the algebra of vectors is contained in algebra of points, it does not follow that in a certain sense algebra of points is not deducible from the algebra of vectors. mathematics, a part often contains the whole. If we repre points by vectors drawn from a common origin, and then dev those relations between such vectors representing points, w are independent of the position of the origin,— by this si process we may obtain a large part, possibly all, of an algebr points. In this way the vector analysis may be made to serve conveniently for many of those subjects which I have menti as suitable for point analysis. The vector analysis, thus enlar is hardly to be distinguished from a point analysis, but the t ment of the subject in this way has somewhat of a make character, as distinguished from the unity and simplicity of subject when developed directly from the idea of something situ at a point.

Of those subjects which have no relations to space, the elementary theory of eliminations and substitutions, including the theory of matrices and determinants, seems to afford the most simple application of multiple algebra. I have already indicated what seems to me the appropriate foundation for the theory of matrices. The method is essentially that which Grassmann has sketched in his first *Ausdehnungslehre*, under the name of the *open product* and has developed at length in the second.

In the theory of quantics, Grassmann's algebraic product finds an application, the quantic appearing as a sum of algebraic products in Grassmann's sense of the term. As it has been stated that these products are subject to the same laws as the ordinary products of algebra, it may seem that we have here a distinction without an important difference. If the quantics were to be subject to no farther multiplications, except the algebraic in Grassmann's sense, such an objection would be valid. But quantics regarded as sums of algebraic products, in Grassmann's sense, are multiple quantities and subject to a great variety of other multiplications than the algebraic, by which they were formed. Of these, the most important are doubtless the combinatorial, the internal, and the indeterminate. The combinatorial and the internal may be applied, not only to the quantic as a whole or to the algebraic products of which it consists, but also to the individual factors in each term, in accordance with the general principle which has been stated with respect to the indeterminate product and which will apply also to the algebraic, since the algebraic may be regarded as a sum of indeterminate products.

In the differential and integral calculus it is often advantageous to regard as multiple quantities various sets of variables, especially the independent variables, or those which may be taken as such. It is often convenient to represent in the form of a single differential coëfficient, as

$$\frac{d\tau}{d\rho},$$

a block or matrix of ordinary differential coëfficients. In this expression, ρ may be a multiple quantity representing say n independent variables, and τ another representing perhaps the same number of dependent variables. Then $d\rho$ represents the n differentials of the former, and $d\tau$ the n differentials of the latter. The whole expression represents an operator which turns $d\rho$ into $p\tau$, so that we may write identically

$$d\tau = \frac{d\tau}{d\rho} d\rho.$$

Here we see a matrix of n^2 differential coëfficients represe
by a quotient. This conception is due to Grassmann, as we
the representation of the matrix by a sum of products, whicl
have already considered. It is to be observed that these mult
differential coëfficients are subject to algebraic laws very sin
to those which relate to ordinary differential coëfficients when t
is a single independent variable, *e. g.*,

$$\frac{d\sigma}{d\tau} \frac{d\tau}{d\rho} = \frac{d\sigma}{d\rho},$$

$$\frac{d\rho}{d\tau} \frac{d\tau}{d\rho} = 1.$$

In the integral calculus, the transformation of multiple integ
by change of variables is made very simple and clear by the m
ods of multiple algebra.

In the geometrical applications of the calculus, there is a
tain class of theorems, of which Green's and Poisson's are
most notable examples, which seem to have been first notice
connection with certain physical theories, especially those of
tricity and magnetism, and which have only recently begun to
their way into treatises on the calculus. These not only find
plicity of expression and demonstration in the infinitesimal c
lus of multiple quantities, but also their natural position, w
they hardly seem to find in the ordinary treatises.

But I do not so much desire to call your attention to the di
sity of the applications of multiple algebra, as to the simpli
and unity of its principles. The student of multiple algebra
denly finds himself freed from various restrictions to which he
been accustomed. To many, doubtless, this liberty seems lik
invitation to license. Here is a boundless field in which ca
may riot. It is not strange if some look with distrust for th
sult of such an experiment. But the farther we advance, the
evident it becomes that this too is a realm subject to law.
more we study the subject, the more we find all that is most u
and beautiful attaching itself to a few central principles. W
gin by studying *multiple algebras:* we end, I think, by stud
MULTIPLE ALGEBRA.

PAPERS READ.

THE HIRUNDO. By REV. THOMAS HILL, Portland, Maine.

THE curve represented (in Watson's coördinates, as modified, Vol. XXII, p. 28, A, of these proceedings) by the equation

$$p = \frac{1 + n\,sin\,\nu}{1 + sin\,\nu}$$

has been named for me, by a friend, Hirundo; from its appearance when n differs from unity (suggestive of *Chæturia pelasgia*).

For the length of the tangent, intercepted by p, we have

$$Dp = \frac{(n-1)\,cos\,\nu}{(1 + sin\,\nu)^2}.$$

For the radius of curvature, $\rho = p + D^2p$, we get

$$\rho = n - \frac{3\,(n-1)}{(1 + sin\,\nu)^2}.$$

When $\nu = \pm m\pi$, m being an integer, $p = 1$; $Dp = \pm (n-1)$.

The curve is evidently symmetrical about the line, $x = 0$.

The cusps are found by putting $\rho = 0$, which gives

$$sin\,\nu_0 = \pm \left(3\left(\frac{n-1}{n}\right)\right)^{\frac{1}{2}} - 1.$$

This shows that there are no cusps unless n exceed unity. When n is less than 1·5, the cusps point toward the axis of symmetry; but when n exceeds 1·5 they diverge. The rate of increase in the divergence diminishes with the increase of n; so that for $n = \infty$ the angle is but $47^\circ\ 3'\ 31''$.

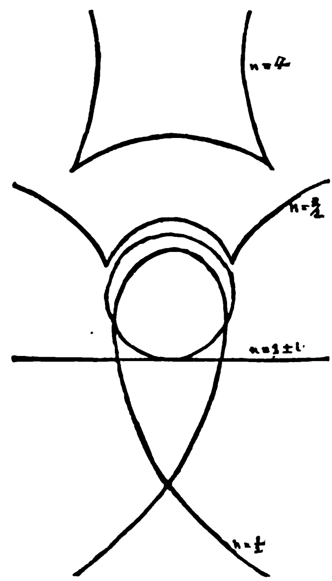
For $sin\,\nu = 1$, $p = \frac{1+n}{2}$; and for $sin\,\nu = -\frac{1}{n}$, $p = 0$.

In the latter case ($p = 0$), we have $x = \left(\frac{n+1}{n-1}\right)^{\frac{1}{2}}$, and $y = n + 1$. In other words, when the tangent to a hirundo passes through the origin, the point of tangency is found upon a curve, $x^2\,(y-2) = y$; which is manifestly asymptotic to the straight lines $x = \pm 1$ and $y = 2$; but approaches the latter asymptote most rapidly.

But the interesting case, of the hirundo itself, is that in which n differs infinitesimally from unity. In this case, it is evident, from the value of ρ, that the curve differs infinitesimally from a circle, except for the infini-

tesimal portion in which $(1+\sin\nu)^2$ is an infinitesimal of as least a
an order as $(n-1)$ is. Calling n, for this case, $n=1-i$, we sh
that as $\sin\nu$ approaches very near the value -1, the radius of cur
lengthens with sudden and greatly accelerating velocity. The curve
crosses itself and runs out into branches nearly straight and fro
first nearly parallel to the axis. But there are no asymptotes; the
gents, to the infinitely distant part of the curve, pass at an infinite dis
from the origin.

Take now $n=1+i$, and the radius, as $\sin\nu$ approaches -1, will d
ish with sudden accelerating velocity. The two sides of the curv
stead of intersecting, recoil from contact. The curve appears to th
as before, like a circle resting on a straight tangent; but in reality



is a breach of continuity at the lowest point; it is an appulse of c
not an intersection.

When n is absolute unity, p and ρ are also unity; the curve is the
circle without the simulated tangent. But the value of Dp shows
for this effect, we must, when the product $(1+\sin\nu)\ (\sec\nu)^{\frac{1}{2}}$ is an
itesimal of the xth order, have $n-1$ of the $(2x+1)$st order.

In order to assist the imagination, let us take the meter as unit
put $n=1-(\frac{1}{10})^{16}$. The curve is now a circle, with the radius of a m
except that, just at the bottom, the radius would lengthen and the
intersect itself. Tangents at that point of intersection would ma
angle so nearly two right angles, that if a straight line were passed
zontally through the point, it would not rise one millimeter abov

tangent, until they were each prolonged to 100 kilometers; and the curve would be included between this line and the tangents.

If we put $n = 1 + (\frac{1}{10})^{16}$, the curve would still be, to any observation of the unaided senses, a circle two meters in diameter resting on a straight tangent. There would, however, be a gap at the bottom twenty-nine hundredths of a millimeter in width, and the curve and the real tangents would be above the horizontal line.

The hirundo may then be described as a circle, whose intellectual law makes it incapable of evolving any forms which are evolved from other circles and in whose own series occurs a sudden break of infinite magnitude, which is, nevertheless, at the point of rupture, not visible to sense; which makes it worth considering in its bearing on the logic of evolution.

SECOND DIFFERENTIALS AND EQUICRESCENT VARIABLES. By Prof. J. BURKITT WEBB, Hoboken, N. J.

[ABSTRACT.]

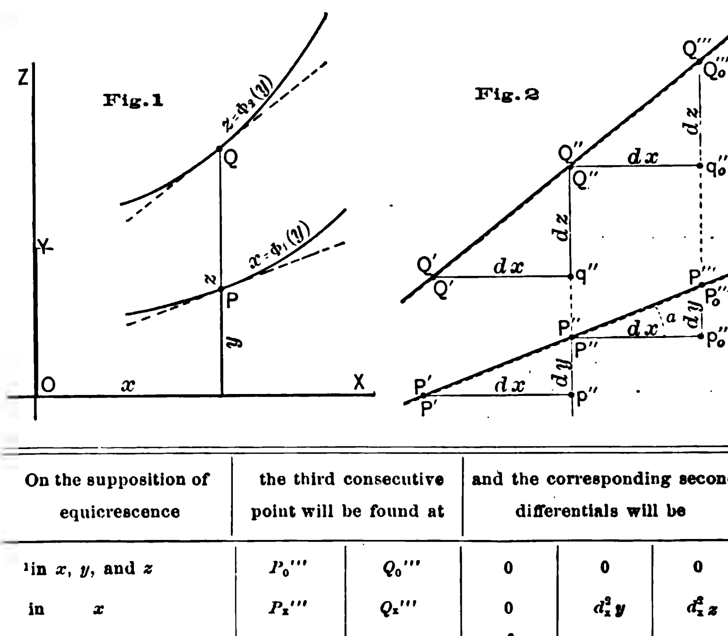
IT is thought that text books on the Calculus do not explain with sufficient clearness the differences and relations between the second differentials of different variables as affected by various suppositions as to the equicrescence of the latter. The subject may be illustrated by the equations

$$x = \Phi_1 (y) \text{ and } z = \Phi_2 (y) \text{ of a line in space.}$$

In Fig. 1 the projections of the line upon the $x\,y$ and $y\,z$ planes are shown, these planes being superimposed to make easier a comparison of the projections; the broken lines are projections of a tangent. Calling the projections of the point of tangency P and Q, we will suppose the regions about P and Q to be infinitely magnified and represented in Fig. 2, being also moved vertically to bring them together into one figure. If P', P'' and P_0''' (the Ps only being mentioned, though the Qs also are understood) be three equidistant points upon the tangent (it being needless to say that they are "the projections of" points) there will be no difference between the two differentials of the same name; *i.e.*, $d\,x$, $d\,y$ and $d\,z$ are constants, which we will suppose belong to the tangent rather than to the curve. The latter will have P' and P'' common with the former, but its third consecutive point will be P''' at a second differential distance from P_0''', this latter point being regarded as an origin of coördinates from which to lay out the second differentials which determine the position of P'''. P should be regarded, to make the conception complete, as lying midway between P' and P''. We will call Fig. 2 the first infinite enlargement. Fig. 3 is obtained by magnifying infinitely the regions about P_0 and Q_0 and bringing

them together vertically. In this second infinite enlargement, second di ferential distances will appear finite and the geometrical connections b tween these quantities may be traced. The addition of these secon differentials to the constant dx, dy and dz of the tangent produces the di ferentials for the curve. In Fig. 2 the curve and tangent should appear t coincide, while in Fig. 3 they will appear separate but parallel. In the o dinary notation of the Calculus to express the second differential, say, y on the supposition that x is equicrescent we must write $\frac{d^2 y}{d x^2} d x^2$, the d in the denominator having the force of an index, signifying the equicre cence of x, as well as of a divisor, we may not remove it from under d^2 but must multiply by dx^2 to neutralize the division; a simpler notation used in the figure and table whereby $d_x^2 y = \frac{d^2 y}{d x^2} d x^2$.

A careful comparison of the table and Fig. 3 will show the effect of th different suppositions possible.



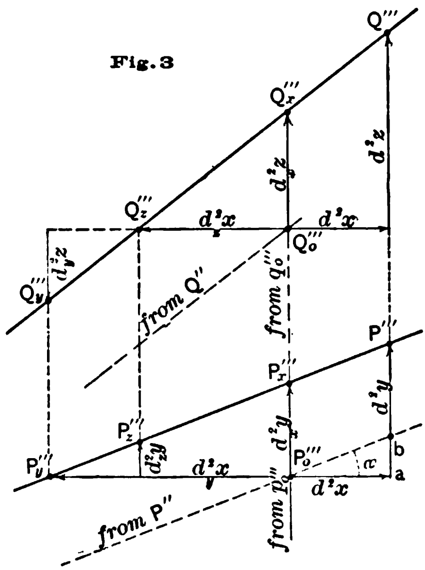
On the supposition of equicrescence	the third consecutive point will be found at		and the corresponding secon differentials will be		
[1]in x, y, and z	P_0'''	Q_0'''	0	0	0
in x	P_x'''	Q_x'''	0	$d_x^2 y$	$d_x^2 z$
in y	P_y'''	Q_y'''	$d_y^2 x$	0	$d_y^2 z$
in z	P_z'''	Q_z'''	$d_z^2 x$	$d_z^2 y$	0
[2]in neither x, y nor z	P'''	Q'''	d^2x	d^2y	d^2z

[1] In this case the curve will become a right line coinciding with the tangent.

[2] P''' Q''' may be taken anywhere upon the curve within a second differential di tance of P_0''' Q_0''.

As an illustration of the geometrical relations evident in Fig. 3 we may produce the ordinary formula for getting the value of the second differential coëfficient of y with respect to x in terms of the second differentials of x and y when neither x nor y is equicrescent. Thus

Fig. 3



$d^2_x y = d^2y - ab$, but $ab = d^2x$ tang a and tang $a = \frac{dy}{dx}$,

therefore $\quad d^2_x y = d^2y - \frac{dy}{dx}\, d^2x = \frac{dx d^2y - dy d^2x}{dx}$

which acquires the usual form on division by dx^2 and dropping the index

$$\frac{d^2y}{dx^2} = \frac{dx d^2y - dy d^2x}{dx^3}$$

SOME PROPERTIES OF THE TORUS. By Professor C. M. WOODWARD, St. Louis, Mo.

IF the circle $(x - a)^2 + y^2 = r^2$ be revolved about the axis of Y, it generates the *torus*

$$(x^2 + z^2 + y^2 + a^2 - r^2)^2 = 4a^2(x^2 + z^2). \qquad (1)$$

If now we cut the torus by a plane parallel to its axis, say by $z = c$, we have as the equation of the section

$(x^2+y^2)^2+2\ (c^2-r^2+a^2)\ y^2+2\ (c^2-r^2-a^2)\ x^2=2\ (a^2\ r^2+a^2\ c^2+$
$-(a^4+r^4+c^4)$

or in general terms

$$(x^2+y^2)^2+A\,x^2+B\,y^2=C,$$

a very general equation of an oval.

If $A=-B$ in (2), this becomes the equation of a Cassinian Oval. ing $A=-B$, we find that $c=r$, and (2) becomes

$$(x^2+y^2)^2+2a^2\ (y^2-x^2)=(4r^2-a^2)\ a^2$$

By taking c of such value that $C=0$, which I find to be $c=a\pm$ would be expected, (2) becomes

$$(x^2+y^2)^2+4\ (a^2-a\,r)\ y^2-4\,a\,r\,x^2=0$$

(using only $c=a-r$), which is the general equation of the Lemni

When $c=a+r$, we have only a point.

Now, it is obvious, that we shall have both conditions fulfilled, na $c=r$ and $c=a-r$, when $a=2\,r$; *i. e.*, *if the gorge-circle of the to equal to the generating circle.* And if a plane is passed tangent to th face at a point of the gorge circle, we have both a Cassinian and a niscate. Substituting in either (3) or (4) we get

$$(x^2+y^2)^2+8\,r^2\ (y^2-x^2)=0$$

which is the Lemniscate of Bernouilli.

NOTE ON TANGENTS TO PLANE CURVES. By Prof. C. M. WOOD St. Louis, Mo.

[ABSTRACT.]

THE following method of writing the equation of a tangent di from the equation of a curve may not be new, but it is new to me convenience may justify its statement.

I begin with the simplest case.

1. All the *kinds* of terms in the general equation of the *second* d are represented in the equation $a\,x^2+b\,x\,y+c\,y=1$.

Multiply by 2 and write in this form:

$$a\,(x\,x+x\,x)+b\,(x\,y+x\,y)+c\,(y+y)=2$$

Prime one-half the x's and one-half the y's, leaving the equation line

$$2\,a\,x\,x'+b\,(x\,y'+x'y)+c\,(y+y')=2$$

is the equation of the tangent at the point x', y'.

2. All the kinds of terms in the general equation of the *third* degr represented in the equation

$$a\,x^3+b\,x^2\,y+c\,x\,y+e\,y^2+f\,x=1$$

Multiply by 3 and write in this form

$a\,(xxx+xxx+xxx)+b\,(xxy+xxy+xxy)+c\,(x\,y+xy+xy)+e$
$(yy+yy+yy)+f(x+x+x)=3.$

Prime two-thirds of the x's and of the y's, leaving the equation linear, and we have the equation required:

$$3\,a\,x'^2\,x+b\,(2\,x'\,y'+x'^2\,y)+c\,(x\,y'+x'\,y+x'\,y')+e\,(2\,y\,y'+y'^2)+f\,(x+2\,x')=3.$$

3. Similarly, taking

$$a\,x^4+b\,x^3\,y+c\,x^2\,y^2+h\,x^3+k\,x^2\,y+e\,x\,y+f\,y^2+gx=1.$$

Multiplying by 4, *priming three-fourths*, etc., and we shall have the equation of the tangent:—

$$4\,a\,x'^3\,x+b\,(3\,x'^2\,y'\,x+x'^3\,y)+c\,(2\,x'\,y'^2\,x+2\,x'^2\,y'\,y)+h(3\,x'^2\,x+x'^3)$$
$$+k\,(2\,x'\,y'\,x+x'^2\,y+x^2\,y'^3)+e\,(x\,y'+x'\,y+2x'\,y')+f\,(2\,y\,y'+2\,y'^2)$$
$$+g\,(x+3\,x')=4.$$

4. Generally

$$a\,x^n+b\,x^m y^p=1$$

in which n is not less than $m+p$.

The equation of the tangent is

$$a\,n\,x'^{n-1}\,x+b(mx'^{m-1}y'^p x+px'^m y'^{p-1}y+(n-m-p)x'^m y'^p)=n$$

5. Three things will be readily seen:

(*a*) The close analogy to differentiation.

(*b*) That constant terms come in through terms of less than the nth degree.

(*c*) Hence, from the last remark, it is evident that if the given equation be strictly homogeneous (without an absolute term), the equation to its tangent will have no absolute term. The tangent will, therefore, always pass through the origin, and the original equation represents either a point (the origin); a system of straight lines intersective at the origin; or an imaginary locus.

6. It is easily seen that the methods above given would derive equations of tangent planes from equations of surfaces.

A NEW DEMONSTRATION OF CAYLEY'S THEOREM ON THE INTERSECTIONS OF CURVES. By H. B. FINE, Princeton, N. J.

[ABSTRACT.]

ATTENTION called to the inadequacy of proofs of algebraic and geometric theorems by method of enumeration of constants: especially as exemplified by this theorem in the consideration and statement of which Cayley overlooked an important class of exceptions.

The corrected theorem stated and demonstrated by use of the Riemann-Roch theorem, the demonstration differing formally though not essentially from Bacharach's (Math. Ann. XXVI).

A curve $f_n = 0$ *is cut by another* $\Phi_m = 0$, $(m >= n)$. *Let* $M = m +$
and μ *have any of the values* 1, 2, . . . *n*. *Then any curve* $\Phi_m = 0$
passes through $m\,n - \frac{\mu-1\,.\,\mu-2}{2}$ *of the points of intersection of* $f_n = 0$ *and* φ
must pass through the remaining $\frac{\mu-1\,.\,\mu-2}{2}$ *points also*, UNLESS THESE
A CURVE OF THE ORDER μ—3.

The theorem is then extended to the case of curves, adjoint and adjoint, intersecting f_n in singular points.

ANY POINT OR PLANE (TANGENTIAL) SINGULARITY IN AN ELEMENT CURVE OF DOUBLE CURVATURE CAN BE COMPLETELY DEFINED OF THREE SINGULARITY INDICES K_1, K_2, K_3. By H. B. FINE, ton, N. J.

[ABSTRACT.]

THE above is one of the central theorems of a paper of mine whi peared in the American Journal of Mathematics, Vol. VIII, No 2.

I have here given a much simpler proof and one which admits of extension to curves of any curvature whatsoever. Indeed, the demo tion given formally contemplates this most general case.

The instrument used is the Grassmann Ausdehnungslehre Analys

PHOTOGRAPHIC DETERMINATIONS OF STELLAR POSITIONS. By DR. GOULD, Cambridge, Mass.

IT has been suggested that a short account of my work upon stella tographs for the attainment of accurate observations might be acce to the Astronomical Section. My intention had been to attend this m as a listener and learner only; but I comply with the suggestion the readily, since by a notable coincidence I spoke upon the same subj this place just twenty years ago, this week. It is true that my c nication then was but an oral one and never reduced to writing; f successful establishment of the Atlantic cable, of which I had just re notice, called me away suddenly, before the time fixed for the r presentation; but an elaborate written memoir upon the subject ha presented to the National Academy, ten days previous, at Northam

The early history of celestial photography is demonstrably and sively American; and its use as a method of delicate quantitative re is very markedly so. Without entering upon the historical data, are of easy access to every investigator, I may mention that No. 77

Astronomical Journal contained nineteen photographic impressions, of as many different phases, of the solar eclipse of 1854 May 26,— the moment of each impression being given to the nearest tenth of a second. These were taken at West Point under the direction of Professor Bartlett of the U. S. Military Academy, and form a part of his memoir, in which he also gives the distances between the cusps as measured by himself with the micrometer in the telescope. Ten years later, in 1864, Mr. Rutherfurd constructed the 11¼-inch photographic object-glass which has acquired so conspicuous a place in astronomical history; and with this, in addition to its other achievements, he obtained sharp photographic stellar images with a definition previously unknown, taking for the first time distinct impressions of stars invisible to the naked eye,— in fact to the 8¾ magnitude for white stars.

After constructing a micrometer of great delicacy, for the measurement of these plates, he measured with this the relative distances and position-angles of the stars which they contained; and in the spring of 1866 he kindly placed in my hands the results thus derived from three plates of the Pleiades, each containing two impressions, taken on the evening of March 10. One of these plates contained forty stars. Bessel's memoirs upon the Pleiades, published in 1844, gave the relative positions of fifty-four stars, measured with the Königsberg heliometer during the years 1829 to 1841. Six of these fifty-four do not belong within the limits of the plate (which contains about one square degree) and ten of them are too faint for the photographic record, so that sixteen of Bessel's list are wanting; but on the other hand there are two additional ones, not observed by him.

From this fact alone it may be perceived that, among the great benefits which astronomy may be justified in expecting from celestial photography, the accurate determination of magnitudes does not find place. The chemical action of the stellar light upon the film is so dependent upon the character of that light, that, in the absence of a correct knowledge of its composition, we are very easily deceived regarding its amount. Thus one of Bessel's stars which was not recorded upon any of Mr. Rutherfurd's plates is estimated by Argelander as of the magnitude 8.0, and by Wolf as 7¾; while five are distinctly recorded which Argelander calls 8½ or less, and eight which Wolf so estimates. The spectroscope would doubtless show a deficiency of the more refrangible rays in the light of the former, and a preponderance of the same in that of the latter.

This series of measurements by Mr. Rutherfurd, together with the computations to which the results were submitted, constitutes if I am not mistaken, the first application of the photographic method to exact astronomical determinations. And the investigation necessarily demanded especial care,— both for guarding the numerical results against sources of unsuspected error, and for fixing the limits within which known theoretical errors would remain unappreciable.

The importance of the successful application of a method so different from all previous ones, and so full of promise, and also the considerable time which would inevitably elapse before the memoir could be printed,

led me at the same time to communicate to the Astronomische Nachricl at Altona, some of the resultant values. In a comparatively short written about the middle of August, 1866, I gave for the ten most con uous stars of the Pleiades, after Alcyone, the corrections, derived one of the photographic plates of March 10, for the values publishe Bessel, of the position-angles and distances from Alcyone in 184C likewise the average discordance found for a single measure.

In the next following year, the Academy had not the means of pri its memoirs; and, as in the meanwhile, Mr. Rutherfurd had measured more of the plates of the Pleiades previously taken, as well as six tional ones taken in the months of January and February 1867, these also computed, and the results added to those from the first three p in the memoir already written.

Various circumstances combined to delay the publication, chief a them being what seemed to me a manifest impropriety in printing th sults derived from photographs and measurements made by Mr. Ruthe and by his own methods, before some account of these methods s have been published by him. His communication on the subject had made to the National Academy immediately previous to my own, bu not yet in such form as he desired for publication.

The result showed a very remarkable accordance with Bessel's det nation for 1840, although the total amount of relative proper-motion ing the elapsed twenty-six years was comprised in the differences.

This memoir still remains in its original form, but unpublished results being deduced from twenty-four photographic impressions, fourteen plates.

In the next year, 1868, I had the gratification of receiving from Rutherfurd, the results of his measurements of thirty-two stars o cluster Præsepe, derived from eleven impressions. These were com in the same way that those of the Pleiades had been, and an anal memoir upon this cluster was prepared for the National Academy.

Before leaving the country, early in 1870, I gave these two memo Mr. Rutherfurd, with the request that he would send them to the pr at the same time with his own paper, already mentioned, but not be The condition of his health prevented him from attending to the m for some time; and in the interval he arrived at the unpleasant disc that the screw of his micrometer had suffered from wear, and to an e which led him to fear a want of that accuracy of which the meth susceptible, and which he hoped to see demonstrated by its very firs plications.

Notwithstanding this possible blemish, it seems to me that the re ought to be now made public in their original form, after due menti the circumstances; and it is among my hopes to be able soon to pu these two memoirs from the original manuscripts of so many years a

The method was received with manifest distrust and disregard ab and, as was but natural for so essential a deviation from former met very many grounds of criticism and objection were brought up. O

the principal of these was the possible distortion of the collodion film after receiving the impressions and before the measurements; but Mr. Rutherfurd speedily disposed of this point, at least so far as the albuminized plates are concerned; and moreover the combination of measurements of the same stars, derived from various plates, will at once make manifest the degree of confidence to which the several values and their mean are respectively entitled.

A far more serious obstacle to accuracy is presented by the difficulty of obtaining absolutely round images. Irregularity of form in the dots formed by the stellar impressions is almost incompatible with precision of measurement; and, as the time of exposure must often be long, the chief problem was not so much to obtain the images, as to insure uniformity of motion in the telescope during the period of exposure. Not that the photographic processes were not troublesome enough, before the introduction of the dry-plate processes,—for very great care and numerous precautions were often necessary to prevent the plates from drying too fast; but far the greatest difficulty consisted in obtaining sufficient precision in the clockwork and equatorial motion of the telescope.

It may easily be imagined how great was my desire, when leaving home for South America, to extend this new method of observation to the southern hemisphere. But the obstacles encountered in the endeavor cannot be easily imagined. Upon these I will not enlarge here, farther than by saying that in Cordoba also the attainment of circular dots for the star-images offered incomparably the greatest of all the difficulties of a practical character. The time of exposure was limited by the maximum size allowable for the large stars; and, previous to 1878, also by the drying of the plate, although exposures for twenty minutes were not unusual. Nevertheless, by dint of specially constructed governors and regulators, and by ceaseless attention, we did succeed in obtaining impressions which to the unaided eye appear absolutely round.

This necessity of long-continued and minute uniformity in the motion of the telescope is, of course, largely diminished by the employment of instruments of large aperture, inasmuch as the necessary time of exposure is diminished in the same ratio in which the amount of light is increased. It is yet further and most notably diminished by the manifold greater sensitiveness of the dry gelatine plates. Yet, notwithstanding all this, the attainment of round images, while almost indispensable for giving to stellar photography that increased accuracy, to which it may lay claim as a means of research in practical astronomy, still demands especial care and precaution.

The Argentine Government cordially afforded every assistance which I deemed it proper to ask, for these investigations. And, although the chief energies of the Cordoba Observatory were absorbed by those investigations for which the institution was established, I had the satisfaction of obtaining a sufficient number of stellar photographs to occupy not only my own life-time, but many more, in their measurement and proper computation.

We photographed no northern stars there, except the Pleiades ar
Præsepe. Of the Pleiades I brought home sixteen plates, with tw
pressions of the whole group upon each, made in five different years
1872 to 1882 inclusive. Although the centre of the cluster never a
a greater attitude at Cordoba than 34° 50′, some of the plates c
seventy stars. All but one of Bessel's stars are there, which b
within the limits of the field,—the missing one being of the magı
9½; and there are yet other stars of the magnitudes 10, 10½ and 1
the Præsepe, there are five plates, and with a correspondingly inc
number of stars.

About seventy southern clusters have been repeatedly photograp
Cordoba, comprising all those of the southern hemisphere which s
important; also somewhat more than a hundred double stars, being
ficient number to serve as a good test of the method. The total n
of photographs now at hand is somewhat less than 1300, only few b
been preserved in which the images were not circular.

Especial attention, however, was given for many years, to takin
quent impressions, at the proper seasons, of four stars selected, o
count of their large proper-motion, as likely to manifest appre
annual parallaxes. The refined and elaborate observations of Dr
and Elkin at Cape Town have been made, computed and published,
the Cordoba photographs have lain untouched in their boxes. Th
but one of my four stars, *β Hydri*, which is not included in thei
Still it will be a matter of much interest to apply the photographic
tigation to the same problem, even if for no other purpose than a
parison of the results of the two methods.

I am convinced that the Cordoba plates contain a large number o
as faint as the eleventh magnitude of Argelander's scale; and b
that these are much the earliest photographs of stars fainter tha
Rutherfurd's of 1865 and 1866. There are several plates, covering
a degree square, which cannot contain less than 550 stars, and I b
that some of them contain a greater number. Such are those of the
ter Lac. 4375, and that near *x Carinae*. The region in the vicin
η Carinae and that magnificent tract in Sagittarius, which is too d
sown with stars to be considered merely a portion of the Milky Wa
yet too large and undefined to be regarded simply as a cluster, wer
of them taken several times, during the years 1875 to 1882, in a se
overlapping photographs, each containing about a square degree, a
corded upon a glass surface of 9 × 12 cm. In their present form th
of course of small value for scientific use, inasmuch as the stars a
crowded for their configurations to be easily perceived; and—alt
these two series form in fact maps of considerable regions in the
still the record is of a very perishable nature, and of small avail for
astronomers until it shall have been translated into an enduring an
merical form by micrometric measurement.

In this connection I may say that one of the greatest of my presen
ieties, regarding the Cordoba photographs, arises from a discovery

ease with which the collodion or gelatine film may become detached from the glass. The Argentine government has assigned a moderate sum for the prosecution of the measurements, and with this some progress has already been made. It is but right to add that the full amount was given for which I asked; still it is now quite inadequate, in consequence of the unfortunate depreciation of the national currency; and, in the present financial crisis there, I cannot reasonably expect more. Yet this matter of prompt measurement appears to me at present much more important than it did while I was unaware of the facility with which the film can blister and peel.

In 1883, after Mr. Common's brilliant success in photographing nebulas with his great three-foot reflector, he proposed to me a joint arrangement for photographing the whole heavens. My work at Cordoba was so near its close that it was out of the question to undertake anything new; but the immense labor requisite for the measurement of the plates would under any circumstances have tended to determine. It is an undertaking demanding the joint energy, application and material resources of a large number of persons, if the results are to be made available for astronomical use; indeed, I see no other astronomical value in the unmeasured photographs than the possibility of confirming at some future epoch, the existence of relative motion previously detected or made probable by some other investigations.

Since then this process of photographic charting is said to have been systematically undertaken by the Brothers Henry at Paris. I have seen none of the plates; but their sharpness is highly spoken of, and the work appears to be prosecuted with much skill and very sensitive plates. There can of course be no question as to the value of any permanent record whatsoever, corresponding to a known date; yet I cannot feel that any essential advance is likely to be made in this way until the photographic record shall have been brought within the range of numerical expression.

The measurements of the Cordoba photographs, thus far completed, are those of the double stars, of the four stars with large proper-motion, of the Pleiades, of the Præsepe and of the clusters Lac. 4375 and κ *Crucis*. The corresponding computations have been made, as yet, only for a portion of the Pleiades impressions, but I am hopeful of completing these at a comparatively early date. We shall then be able not only to compare the results with Bessel's of forty-five years ago, but to test the deduced values of the proper-motions by means of the photographic determinations of 1865 and 1866. Meanwhile the valuable memoir of Wolf has been published, giving closely approximate positions for 571 stars of the group, and Dr. Elkin has recently been executing at New Haven a heliometric triangulation of the principal stars. Our photographic results will have to be confronted with his delicate heliometric ones; and should they bear this test with tolerable success, it will be all that can reasonably be desired.

SOME ACCOUNT OF A NEW CATALOGUE OF THE MAGNITUDE OF SOUTH STARS. By EDWIN F. SAWYER, Cambridge, Mass.

THE present short paper is merely intended to announce the complet in the immediate future, of a work undertaken in 1882, namely, the de mination of the relative magnitude of the stars included between equator and 30° S. Dec., and not fainter than the 7th magnitude. fact the work is a revision of so much of Dr. Gould's valuable catal the Uranometria Argentina, as is included in the above limits, and his alogue has been used as the basis of the undertaking. The observat have been made by Argelander's well known method of step estimati the stars being gathered into convenient sequences, and these seque formed from the stars as closely adjacent as possible; thus reducing minimum errors arising from atmospheric causes and the unfavorabl uation of the stars, except in a few sequences formed from bright s necessarily more widely scattered. In making the observations, an op glass magnifying two and one-half diameters has been employed and glass placed slightly out of focus, expanding the stars into disks of li this method after repeated trials appearing to give the most reliabl sults, especially where the stars are colored. The observations have erally been made during evenings free from the moonlight and clouds haze. As at first planned, each star was to have been observed but (owing to the press of other astronomical work on our leisure time) after the observations had been practically completed in 1885 (compri some 3500 stars) and while their reduction was under way, it was dec to reobserve each star once in ordinary cases, repeatedly where large cordances appeared. This duplication of the observations, while i creased the amount of time and labor which I had originally intend devote to the undertaking, would I felt, be justified by the enhanced v of the results; observations were therefore resumed in 1886, and hoped that another year will find the work completed and ready for p cation.

The number of stars comprised will approximate 3500, and the ave number of observations for each star will be about three and one- During the progress of the work one variable star has been discove and large discordances in the observations of several stars may poss lead to the detection of others.

As a test of the character of the work, the following results have deduced from a partial discussion of the observations of about 900 s observed from two to five times each.

To determine the accidental errors of observation, I have found 593 stars, observed twice, that the average difference between two i pendent determinations of a magnitude of a star is .112 of a magnit which corresponds to a probable error of a single observation of ± 0 a magnitude. There appears to be no sensible difference in the valu this element dependent on the zenith distance.

The process of reduction adopted presumably excludes a liability to systematic deviation from the system of magnitude of the Uranom

Argentina, which, as is known, is based on that of the Uranometria Nova. But a direct test has been made to verify this point, by employing stars observed three or more times. Taking the difference between my mean magnitude and that of Dr. Gould's, and classifying according to magnitude we have the following table:—

Mag.	No. of stars.	G.—S. Systematic difference.	Probable error of a difference. G.—S.
1—4	49	—.033	±.106
4—5	46	—.004	±.109
5—6	59	+.017	±.093
6—7	98	+.002	±.073
	252		±.091

The values in the third column are merely nominal and afford satisfactory evidence of the coincidence between my magnitude scale and that of Dr. Gould's. From the fourth column, it appears as would naturally be expected that the estimates for the fainter magnitudes are ratably the more accurate. The probable error of a difference G.—S. is on the average .091 of a magnitude. Assuming for want of a criterion that both catalogues have equal weight, this corresponds to a probable error in each of .064 of a magnitude.

I have not limited the observations to the stars only contained in Dr. Gould's Catalogue, but have inserted all objects which have appeared to be in the neighborhood of his fainter class.

The number of such objects is surprisingly small, probably not over seventy-five; and this, in connection with the observed small probable error appears to be a most satisfactory evidence of the high degree of precision of the magnitudes of the Uranometria Argentina.

A COMPARATIVE ESTIMATE OF METHODS AND RESULTS IN STELLAR PHOTOMETRY. By S. C. CHANDLER, Jr., Cambridge, Mass.

[ABSTRACT.]

THE main object of this paper is to give the results of an examination of various catalogues of stellar magnitude which have appeared during

the last twelve years, with special reference to the question of the com-parative value of instrumental and non-instrumental methods in s photometry.

Among the topics discussed are the light ratio for the unit of m tude; the wide discordance in the measurement of light differenc various photometers; their inability to furnish a trustworthy iso-p metrical scale; the existence and probable causes of the various sy atic mutual deviations which they exhibit; and the conclusions whic be drawn as to the present condition of stellar photometry.

The ground is taken that instrumental photometry is so far pract a failure, in that it furnishes contradictory solutions of the problem which it was especially needed, and has besides failed to attain t gree of precision which pertains to the non-instrumental method.

COMPARISON OF THE BOSS AND AUWERS DECLINATION-STANDARDS

HENRY FARQUHAR, U. S. C. and G. Survey, Washington, D. C.

[ABSTRACT.]

THE standard of Dr. Auwers' "Fundamental Catalogue" (A. G. 14, 17) is, for declinations, that of the recent Pulkowa observatio which all other authorities used in the catalogue are adjusted by sy atic corrections, from a comparison in order of declination and anot order of right-ascension. Prof. Boss's N. B. Survey Catalogue l been similarly compared with the Pulkowa declinations, the mean ences (shown in order of declination in an accompanying table; th order of right ascension having no significance) are remarkably u in sign, all those north of 50° being positive, increasing to 0.″17 80°, and all south of 50° negative, larger for lower stars, and surp 0.″3 south of —10°. Applying to these differences the correction — +0.″30 sin ζ (ζ being the zenith-distance at Pulkowa, 60°—δ) th much reduced, and the uniformity in sign disappears; there is a s tion, however, of an undulatory inequality, of a 30° period. The correction, if it really exist, probably denotes a periodic gradu error in a meridian circle; the former pretty clearly denotes an impe corrected tube-flexure. The error may be in the Pulkowa declinati in some of the sources drawn upon by Boss. The residuals could ther diminished by a small term in cos ζ, indicating flexure from a south of Pulkowa; or by a small term in tan ζ, showing an inaccur lowance for refraction in one or other catalogue; but the gain is t certain to justify a positive conclusion.

A NEGLECTED CORRECTION IN THE USE OF REFRACTION TABLES. By Prof. CLEVELAND ABBE, U. S. Signal Office, Washington, D. C.

[ABSTRACT.]

THE refraction tables of the *Fundamenta*, the *Tabulæ Regiomontani* and the Poulkova tables hold good, respectively, for the latitudes of Greenwich, Königsberg and Poulkova, with respect to atmospheric pressure as measured with mercurial barometers at those places.

In using these tables in other latitudes, we must recall that the height of the barometer is not a true index of atmospheric pressure until it is corrected for the effect of variations in gravity. This is accomplished by simply adding one more factor to the refraction formula. Thus those who at the latitude θ make use of either of these three tables, instead of the formula of refraction

$$R = a \tan Z \, (B\,T)^{A} \, \gamma^{\lambda}$$

where B is the observed height of the barometer and T the correction for the attached thermometer, should use the corrected formula

$$R = a \tan Z \left(\frac{1 - 0.00259 \cos 2\,\theta}{1 - 0.00259 \cos 2\,\theta_0} B\,T \right)^{A} \gamma^{\lambda}$$

where θ_0 is the latitude for which the table is computed. As A differs very little from unity, the effect of this correction is to affect all the refractions computed for a given observatory in the ratio of the above factor.

Although this correction is small, yet it is quite appreciable in refined work on declinations and partly explains systematic differences in declinations given by star catalogues.

ON CERTAIN DISCONTINUOUS AND INDETERMINATE FUNCTIONS, WITH APPLICATIONS. By Prof. CHARLES K. WEAD, Malone, N. Y.

ON THE LIMITATIONS IN THE USE OF TAYLOR'S THEOREM FOR THE COMPUTATION OF THE PRECESSIONS OF CLOSE POLAR STARS. By Prof. WM. A. ROGERS and ANNA WINLOCK, Cambridge, Mass.

ON A METHOD OF DETERMINING THE CONSTANTS OF PRECESSION, WHICH IS PARTIALLY INDEPENDENT OF THE VARIATIONS OF THE PROPER MOTION OF THE STARS EMPLOYED. By Prof. WM. A. ROGERS, Cambridge, Mass.

ON THE DEGREE OF ACCURACY WHICH MAY BE EXPECTED FROM CHRONOGRAPH RECORDS. By Prof. WM. A. ROGERS, Cambridge, Mass.

COMPARISON OF THE PLACES OF THE PLEIADES AS DETERMINED
KÖNIGSBERG AND YALE COLLEGE HELIOMETERS. By Dr. W. L.
Yale College Observatory, New Haven, Conn.

ON SOME MECHANICAL ATTACHMENTS (PARTLY NOVEL, AND PARTL
FOR FACILITATING THE ASTRONOMER'S WORK WITH THE EQUA
By Prof. DAVID P. TODD, Amherst, Mass.

CHANGE IN LATITUDE OF THE SAYRE OBSERVATORY. By Prof.
DOOLITTLE, Bethlehem, Pa.

ON THE USE OF THE ZENITH TELESCOPE FOR LATITUDE. By S. C.
LER, JR., Cambridge, Mass.

MAGNIFYING POWER OF TELESCOPES. By HENRY M. PARKHURS
York, N. Y.

TELESCOPIC OBSERVATIONS OF METEOR TRAINS. By E. E. BA
Vanderbilt University, Nashville, Tenn.

A NEW THEORY OF GRAVITATION. By JOHN H. KEDZIE, Evansto

ON A METHOD OF OBTAINING THE MEAN APPARENT DIAMETER
SUN. By SAMUEL MARSDEN, St. Louis, Mo.

THE TANGENT INDEX: AN INSTRUMENT TO EXHIBIT THE DIRECTIO
TANGENT TO THE EARTH'S ORBIT, AND THE DIRECTION OF THE
MOTION IN SPACE AT ANY TIME. By Prof. JOHN HAYWOOD,
erville, Ohio.

SECTION B.

PHYSICS.

ADDRESS

BY

C. F. BRACKETT.

VICE PRESIDENT, SECTION B.

THE ELECTROMOTIVE FORCE OF THE VOLTAIC CELL.

ALMOST with the beginning of our knowledge of electricity produced by contact of dissimilar bodies, a controversy arose concerning the seat of the electromotive force involved, and, though nearly a century has since passed, the question is still before us. It will be useful, I think, to review the course of inquiry and opinion relating to this matter, even at the risk of traversing familiar ground.

In the year 1789, Galvani, by accident as appears from his own account, made an observation which opened a new field of research and connected his name inseparably with electrical science. The account which he gives of it is very simple. "I dissected a frog and prepared it as shown in the figure."—The figure represents the hind legs of a frog stripped of their skin and with the crural nerves laid bare but still connected with the portion of the spinal cord from which they arise.—"With no definite purpose I laid it on a table near which an electrical machine was standing. One of my audience brought the point of a knife near the crural nerves when the muscles of the legs were contracted as if they had been seized with convulsions. Another of the bystanders thought he noticed that the contractions occurred only when a spark passed from the conductor of the machine; and, being struck with the novelty of the thing, he called my attention to it, as I chanced at the moment to be occupied with something else. I was at once impelled to investigate and find out the secret of it."

Galvani soon confirmed the observation that the contractions

occurred only when a spark passed, and so did not doubt that he had to do with an electrical phenomenon. The identity of the electrical spark with the lightning flash had been shown by Franklin, and Galvani naturally sought to ascertain whether the muscular contractions could be induced by disturbances of atmospheric electricity. They occurred as he expected, and sometimes even when the electroscope did not indicate any disturbance.

Wishing to make more extended observations he made a number of frog-preparations, and, having inserted an iron hook into the portion of the spinal cord attached to each of them, he hung them on an iron fence that he might observe how they were affected. There being no obvious result, after some time, he bent one of the iron hooks, without expecting any definite effect, so that the muscles accidentally came in contact with the iron of the fence, when immediately violent contractions were manifest in that particular preparation. Seeing that he had accidentally formed a closed circuit, consisting of the frog-preparation, the hook and the iron of the fence, he suspected that the electricity of the atmosphere had nothing to do with what he had observed. Accordingly, he made fresh preparations and found that he could induce the contractions at will, by merely touching the nerve and the muscle with two different metals which at the same time touched each other. On replacing one of the metals with a non-conducting body no contractions occurred. He, therefore, concluded that the seat of the electromotive force (to use the modern term) is in the tissues themselves, and that the metals only serve as conductors. He had, as he believed, discovered the true agent to whose action the life processes of the organism are due. His experiments and opinions were quickly made known and the greatest enthusiasm prevailed among his contemporaries who busied themselves in repeating and extending his experiments and in setting up most wonderful theories derived, with more or less plausibility, from them.

The so-called nervous force of the physiologists was regarded by the new disciples as superseded by "animal electricity," and some of the greatest names of the time adhered to this belief, among whom may be mentioned Humboldt and, at first, Volta. There were not wanting, however, those who protested. Gren of Halle declared it premature to attempt to explain physiological processes by means of animal electricity, which, in all probability had no existence; and Reil, his colleague at Halle, said that the new ex-

periments only proved a great irritability of the nerves for electricity which came from without the organism. "The seat of the irritation is in the metals; that of the irritability is in the organism." Volta, however, by far more able and active in his researches than any other, did not long remain in accord with Galvani. He was soon able to show that the only condition requisite for the production of the contractions in the frog-preparation is contact of heterogeneous surfaces of bodies so arranged as to form a circuit with it. Galvani replied by producing an experiment in which the contractions were induced on touching the nerve with the skin or with the muscle at the extremity of the leg,— the leg being flexed so as to allow such contact. Volta pointed out that two surfaces could hardly be more dissimilar than these, and that this experiment only showed the generality of the law.

Volta found that the organs of special sense, when acted on by two metals in contact, can be excited to their proper action, just as they are by slight discharges from the electrical machine. He found that the peculiar taste-sensation excited when two metals in contact are placed on the tongue depends on their relative position on the tongue, and, by means of these sensations he made provisional arrangements of the common metals in three classes,— a provisional arrangement in "tension series" which he subsequently, in 1801, completed by means of the condenser electrometer.

Speaking generally, he showed that in order to the production of "galvanism" (for he appears to have been the first to use this term, 1796) either two different metals and a liquid, or two different liquids and one metal are requisite, and, further, he pointed out that three or more metals in contact cannot produce an electrical current. Volta assumed a definite force which is exerted at the contact between two metals in consequence of which they acquire opposite charges. In order to confirm his views he devised the experiment which is still everywhere shown as "Volta's fundamental experiment." It consists in bringing two different metals in contact by means of insulating handles, and, on separating, testing them by means of the electroscope when they are found in opposite electrical states.

In 1795, Dr. Asch, of Oxford, observed that when a zinc plate is in contact with one of silver, with a film of water between them, the zinc becomes oxidized. Humboldt, repeating the experiment, observed minute bubbles of hydrogen forming on the surface of

the silver. These are the first observed facts which were soon to be made important in a contest against Volta's theory of contact action between the two metals. It must be remembered that the doctrine of the "conservation of energy," even if some glimmerings of it had here and there appeared, had not yet been announced, nor was the science of chemistry very far advanced.

In 1797, Coulomb presided over a commission appointed by the Mathematical and Physical Section of the National Institute of France, to investigate the question of "animal electricity." The results of Volta's researches were confirmed but the commission did not go farther. Meantime, Volta applied himself to find the means for increasing the effects which he ascribed to metallic contact. In March, 1800, he wrote his famous letter to Sir Joseph Banks, at that time president of the Royal Society, London, describing the now well-known "pile" and "crown" of "cups." With this apparatus he easily produced all the physiological effects which he had investigated in his earlier experiments. He distinctly declared his belief that the seat of the electromotive force is at the metallic junctions.

Fabroni, in 1796, disputed the validity of Volta's theory of contact action, and, referring to Dr. Asch's observation of the previous year, showed that when zinc and silver, for example, are in contact, and are brought into water, the latter is decomposed and the zinc is oxidized, but that the same does not happen when the zinc alone is placed in water. This oxidation he refers to the relation of cohesion to that of attraction existing between the zinc and the oxygen of the water, or, as we now say, to "chemical action." The electrical disturbance he regarded as the consequence, but not the cause of the oxidation. He was, therefore, in some sense, the founder of the so-called chemical theory of galvanic action.

We have, then, almost at the outset, three distinct theories of galvanic action. That of Galvani, or that of "animal electricity," soon retired from the field, while the contact theory of Volta and the chemical theory of Fabroni were destined to a longer contest, which, with varying fortune, has continued to the present time.

Sir Humphry Davy quickly availed himself of Volta's invention in a series of brilliant, electrolytic researches. He noted the invariable order in which the metals and metallic oxides appear at the negative pole of the battery, and oxygen and the acids appear

at the positive pole; and concluded that chemical and electrical actions are produced by one and the same cause, acting, in the one case, upon the particles and in the other on the masses. He, therefore, assumed that the action of the voltaic pile depends on the difference in the oxidation of the two metals employed. If this be true, a voltaic element which contains but one metal should develop just as much electricity as one which contains two if provision be made for the necessary oxidation. He, therefore, constructed elements with but one metal and two liquids, and varied the arrangement in three ways. In the first instance, he employed one metal and two liquids, one of which could oxidize the metal while the other could not. In the second he employed a metal which can react with sulphureted hydrogen,— for example, he used silver and for liquids solution of potassium sulphide and water. In the third, he employed silver with potassium sulphide and an acid. The strengths of the currents in these combinations were in the order of their description. These experiments seemed to speak against the contact theory, though the supporters of that theory replied that the greater or less oxidation which the metal suffered was in consequence of the electricity excited and not the cause of it. Davy himself held a view which combines the theory of metallic contact action with that of chemical action, viz.: that the electrical excitation is due both to the metallic contacts and to the metal-liquid contacts, and he points out that the chemical action is essential to the production of a current. He held that the electrolytic decomposition of bodies by the battery restores to the elements of which they are composed, as they are set free, the opposite electrical states natural to them before union. Davy regarded the heat and light which accompany the combination of certain bodies as an electrical phenomenon, inasmuch as combination is but the consequence of electrical attraction. Berzelius made this idea the foundation of his electrochemical theory of combinations.

In 1781, Lavoisier and Laplace instituted experiments by which they brought the excitation of electricity and chemical processes into close relation. They, however, did not regard the results of their experiments from the chemical point of view, but rather as related to changes in the states of aggregation. Yet this relation was too close not to appear, as the electrical view of chemical action more and more gained an entrance into science.

Of course they had no appliance with which to detect electrical disturbances except the electroscope. They employed well insulated cups in which were placed iron filings, and upon which they poured in the one case sulphuric acid, and in another nitric acid. Thus there were evolved in the one case hydrogen and in the other nitric oxide with nitrous anhydride. These, escaping, left the cup negatively electrified. The same result followed in other similar experiments in which the reactions evolved gases. They reasoned that the positive electricity was carried away by the gas and so were led to try if the evaporation of water would produce the same result. Water was, accordingly, poured on incandescent coals which were insulated and traces of negative electricity were found. We need not stop to dwell on the obvious sources of error in these experiments. It is enough for our purpose that in them we find the first attempt to discover some relation.

Davy, with perfectly definite intent, experimented on the electrical relations involved in chemical combinations, with the result that in some of the most energetic chemical combinations, such as the combustion of phosphorus, no trace of electricity is apparent. These experiments, he thought, gave great support to his electrochemical theory, in accordance with which, in such cases, the two electricities unite to produce fire and so entirely disappear.

Davy's results were contested by Pouillet, in the interest of the chemical theory of the voltaic pile.

He finds that mere alterations in the state of aggregation do not produce electrical disturbance. Hence water evaporated from platinum does not produce electricity either in the vapor or on the metal. But electricity is always produced when water is evaporated from other bodies which act on the vessel from which the evaporation takes place. So, too, when water is evaporated from alkaline bodies the vessel is positively charged, but if some acid remain behind, the vessel is negative, etc.

When coal is burned, if care be taken to prevent the resulting CO_2 from coming in contact with it, the coal is charged negatively and the CO^2 positively.

Becquerel does not agree wholly with these results and we may, without going into details, remark that the sources of error are too obvious to leave us in any surprise at the result.

Pfaff, one of the most uncompromising of the supporters of the contact theory of Volta, after many years of careful experiment,

in 1840, reviews the work of Pouillet with much better appliances, and with greater care in the details, and gets negative results both in the combustion and in the evaporation experiments.

He institutes a series of experiments for the purpose of throwing light on the electrical relations between the so-called moist conductors and the metals employed in the galvanic circuit. It will be sufficient to give some of the most important results which he reached. He finds that there is no relation between the chemical action and the electric current which can be expressed as a law. Also, that very strong electrical manifestations are present for days where there is no chemical action. As respects the kind of electricity which will result from contact of the different metals with the different liquids, the following statements are true, viz.: the alkaline liquids, in general throw the metals into a negative state, and the more strongly the nearer the metals stand to the positive end of the "tension-series." Concentrated acids in contact with the metals make them positive. All metals, without exception, are positive with nitric acid. In contact with sulphuric acid, they are divided into two groups. Those lying nearer the negative end of the tension series, gold, platinum and copper, are positive,—the others negative. Similar relations exist with hydrochloric acid. When solutions of the heavy metallic salts are employed, the metals in contact with them always acquire the same kind of electricity which would be manifest on simple contact with the metal contained in the solution in a given case.

In most cases, the metals show permanently the same kind of electricity. In a few cases the electricity at first excited falls off and finally that of the opposite name appears.

Finally, Pfaff gives what he calls the *experimentum crucis* in favor of the contact theory and against the chemical theory of the English electricians, chief among whom is Faraday.

Two graduated tubes have each, at the commencement of the lower third, a small opening through which is passed, quite tight, a platinum wire. To this in the one case is attached a piece of zinc, and in the other a piece of platinum. These tubes, open below, stand in a vessel containing dilute sulphuric acid. By repeated experiments was found exactly how much hydrogen was liberated by the ordinary chemical process, in a given time. Then a similar piece of zinc was hung on the platinum wire, and, as quickly as possible, the wire was connected to the wire of the sec-

ond tube supporting the platinum. Here was a simple galvanic combination of zinc and platinum. In this case, at least, a part of the affinity which was expended in dissolving the zinc would be transferred to the platinum, the development of hydrogen on the zinc would be diminished and what was wanting there would be set free from the platinum. But as a matter of fact there was just as much hydrogen developed on the zinc as before and a small accessory amount was developed on the platinum. An amount of oxygen corresponding to this must have been combined with the zinc. The two processes, therefore, go on independently: the chemical process by itself, and decomposition of the water through the agency of the electricity excited by the contact of the metals just as if it were by itself. And yet Pfaff, in the course of his memoir, remarks that he has endeavored to demonstrate the insufficiency of the data of the so-called chemical theory of the English as well as its contradiction of the general principles of physics and its arbitrary character!

It may be remarked, in taking leave of the labors of Pfaff, that he published a series of experiments in 1829 having for their object to show that the charges which two metals acquire when brought in contact are not due to the action of the air or surrounding medium. It consisted in placing them under the receiver of an air pump which could be exhausted or filled with different gases, and ascertaining how the charges were affected. The results, as he believed, were favorable to the contact theory.

In 1841, Peclet published a "Memoir on the Development of Static Electricity during the Contact of Bodies." All his studies have reference to the static charges produced by contact. He did not consider the closed circuit. He uses the word "contact" in its simple sense with no reference to the cause operating. He employed a sensitive condenser electroscope having its plates composed of gold leaf laid on depolished glass and covered with several layers of varnish. The whole was placed under a bell-jar with calcium chloride to secure a dry atmosphere.

In the course of his inquiry he repeats and confirms the fundamental research of Volta. As the outcome of several different plans of experimentation, the conclusion is reached that, in order to charge the condenser, it is necessary to establish a communication between the two plates by means of a metallic arc interrupted by a liquid or moist substance placed between two metals of dif-

ferent nature. And further,— in any one of the different modes of experimentation, so long as the same metal and the same solution are employed, the effect produced is independent of the degree of concentration of the liquid and so of the energy of the chemical action when such action exists. All the phenomena observed could result, he thinks, from contact of the metals with each other, from contact of metals with liquids, from the contact of liquids with each other, or from all these contacts combined.

In order to study these various circumstances separately he had recourse to metallic discs furnished with insulating handles. First discs of copper and zinc eight centimeters in diameter, not plane nor perfectly polished, were used. Pressure and friction preceding separation were found to be without influence. When the discs were separated by sliding one away from the other, or by removing one from the other while held at a sensible angle, there was no result. Diminishing the amount of surface in contact diminished the effect. On employing perfectly flat discs, so that the plates adhered to each other, there was no result. But on deforming their surfaces by grinding with emery the electroscope gave indications which increased with the amount of deformation.

A condenser formed of copper and zinc plates was joined up by means of a U tube containing in one limb an acid solution and in the other an alkaline solution. The condenser received a greater charge when the zinc communicated with the acid solution than when it communicated with the alkaline one.

In order to observe the difference in the effects produced when metals are put mediately in contact by means of a metallic arc and by means of liquid or moist conductors, use was made of varnished discs. One of these being of gold, others of tin, lead, iron, bismuth and copper were successively joined up with it.

There was always an increase of potential and a change of sign when one passed from the metallic to the liquid means of communication. It results from this, contrary to the theory of the pile given by Volta, that the electrical potential developed by contact of the metals with the liquids is by far more efficacious than that developed by the metallic contacts. The metallic plates hardly play any other rôle than that of conductors. When metallic plates are put in communication by means of an arc formed of different liquid conductors, the effect depends only on the liquids which touch the plates and is independent of the intermediate liquids. If the two

thumbs be moistened, the one with an acid solution and the other with an alkaline solution and then be brought in contact, the index fingers may be applied to the poles of a sensitive electroscope without affecting it.

It results from all these experiments, we may conclude, that there is a development of electricity between metals in contact with each other and between metals in contact with liquids; that the contact of all the metals with gold renders them positive whether the contact be direct or by means of an intermediate metallic conductor; but if the communication between gold and the other metals be effected by means of liquid conductors the difference in potential is, in general, much greater than in the last case and of the contrary sign. So if one touch the plate of a condenser with a metal which is held in the hand and at the same time touch the other plate with the finger there is a development of electricity at the contact of the metals with each other and at the contact of the fingers with each of them, and the effect observed is the algebraic sum of the three partial effects. But as the effects of the contacts of the metals and liquids are much greater than those of the contacts of the metals themselves, the difference of potential produced is due almost entirely to the contact of the metal and of the gold with the fingers.

Peclet next proceeds to inquire whether the electricity developed on contact of metals with each other and with liquids is to be referred to contact simply, or to chemical action. He refers to Pfaff's experiments, already cited, and to De la Rive's objections to them. These objections were: (1) that the electricity might be produced by pressure; and (2) that it is impossible to be sure that there might not be traces of moisture in the air and gases surrounding the metals, notwithstanding the precautions taken.

As to the first, it is disproved by direct experiment. De la Rive believed his second objection supported by the following experiment: — A condenser was made consisting of a plate of zinc furnished with a platinum wire and completely covered with varnish, and of a copper plate, varnished only on its obverse surface. On making communication by means of a wire, there was a deviation showing a charge, but on increasing the number of coats of varnish on the zinc plate this deviation diminished. De la Rive believed the effect due to the more complete shutting out of the air by the additional layers of varnish. But the continuity of the

varnish does not permit such a supposition, while it is clear that the effect should diminish in proportion to the thickness of the dielectric between the condenser plates.

To remove all doubt, Peclet made a condenser having plates six inches in diameter, perfectly plane, and covered, at first, with five or six layers of varnish. The result was that, on increasing the number of layers of varnish, subsequently the deviations of the electroscope diminished. It appeared that on increasing the number of layers of varnish indefinitely, and increasing the number of contacts, the same deviations could be produced. These facts leave no doubt in respect to the origin of electricity on the contact of metals. But there is one fact to which it is impossible to object, viz.: when zinc is touched by a metal it loses positive electricity, but when it touches a moist or liquid conductor it loses negative electricity. Consequently, it cannot be supposed that the electricity which it receives on contact with copper results from contact with the air, since it would then have a contrary sign.

As regards the effects of contact of metals with liquids, Peclet cites the experiment with the condenser, of gold plates, in which a metal is held in the hand and brought in contact with one plate while the finger touches the other plate, the fingers having been previously washed with distilled water. The effects are much smaller than those which result from contact of metals with liquids and so must be regarded as being the difference of the effects produced by contact of the fingers with the metal. Moreover it has been shown by several physicists that electricity is produced by contact of water with platinum, plumbago, anthracite, peroxide of manganese, etc., — substances between which there is no chemical action. For these at least it must be admitted that there is electrical disturbance without chemical action.

Among other facts having a bearing on this matter it may be mentioned that absolute alcohol is without chemical action on several metals, and yet these metals, when moistened with this liquid show electrical disturbances. The same is true of caustic potash and iron. Finally, it seems to be impossible not to admit that there are cases of electrical excitation between metals and liquids which do not act chemically upon them.

Peclet's results are briefly summed up thus :—

(1) That metals produce electricity by contact as Volta an-

nounced, and that it is not possible to ascribe this to pressure, friction, or to the action of the surrounding atmosphere.

(2) That in a chain formed of several metals the result is the same as if the extreme ones were in immediate contact, as Volta announced.

(3) That Volta's theory of the difference of potential in the pile is inexact, inasmuch as the principal effects come from the action of the metals on the liquids, and the action of the metals on each other tends to diminish the whole effect.

(4) That when two metals are separated by a chain of several liquids communicating between them, the effect is the same as if the liquids which touch the metals were in immediate contact. This law is for liquids analogous to that which Volta found for metals.

(5) That in the contact of certain liquids and certain metals, electricity is developed without it being possible to admit chemical action between the two.

The remarkable series of researches in which Faraday sets forth the laws of electrochemical action was brought to a close at the end of 1833.

Number 857 of this series reveals the state of Faraday's mind respecting this matter at that date. I quote it: "Intending hereafter to apply the results given in this and the preceding series of Researches to a close investigation of the source of electricity in the voltaic instrument, I have refrained from forming any decided opinion on the subject; and without at all meaning to dismiss metallic contact, or the contact of dissimilar substances, being conductors, but not metallic, as if they had nothing to do with the origin of the current, I am still fully of opinion with Davy, that it is at least continued by chemical action, and that the supply constituting the current is almost entirely from that source." We cannot fail to be impressed with the idea that, whether he had at that time distinctly formulated it or not, considerations connected with the doctrine of energy were influencing him. So, too, Peclet remarks, in 1841, in reply to a suggestion of De la Rive, that the electrical excitement which attends the contact of two varnished plates is due to pressure, "the suggestion is of no weight for one cannot see whence the electricity could come."

Early in 1834 Faraday presented the eighth series of Researches. "On the Electricity of the Voltaic Pile: its source, quantity, in-

tensity, and general characters." Here he expresses himself with great decision. One or two extracts will show how he regarded it.

In number 916 Faraday says:—"The electricity of the voltaic pile is not dependent either in its origin or its continuance upon the contact of the metals with each other. It is entirely due to chemical action and is proportionate in its intensity to the intensity of the affinities concerned in its production: and in its quantity to the quantity of matter which has been chemically active during its evolution. This definite production is again one of the strongest proofs that the electricity is of chemical origin."

In number 947 he speaks as follows: —"We seem to have the power of deciding to a certain extent in numerous cases of chemical affinity, which of two modes of action of the attractive power shall be exerted. In the one mode we can transfer the power onwards, and make it produce elsewhere its equivalent of action; in the other it is not transferred, but exerted wholly at the spot. The first is a case of volta-electric excitation, the other ordinary chemical affinity, but both are chemical actions and due to one force or principle." Numerous other passages to the same purport might be cited to show how completely Faraday adopted the chemical theory of the action of the pile.

The well-known observations of Schönbein, respecting the passivity of iron in nitric acid, made early in the thirties, led to a new view of chemical action. The effects of this seem to be found in Faraday's doctrine of polarization, which prevails in all his expositions of galvanic phenomena. The key to the whole is found in the word "tendency." Schönbein says: "I maintain that any tendency of two different substances to unite chemically with one another must be considered as chemical action, be that tendency followed up by the actual combination of those substances or be it not; and that such a tendency is capable of putting electricity into circulation."

More explicitly, and in reply to criticisms of Herr Pfaff, Schönbein declares himself at one with the strictest contact-theorist concerning the assumption that there are many hydro-electric circuits which act voltaically without any evident chemical action occurring in them, either of combination or decomposition, before the closing of the circuit. Yet he does not seek for the cause of the electrical phenomena presenting in such voltaic cells, in the mere contact of different materials, independent of chemical action, but in a chemical attraction conditioned on contact, which a constituent of

the cell exercises towards one of the ions employed in the formation of the cell.

The chemical attraction of a substance for oxygen or for hydrogen, the constituents of water, he ascribes to a disturbance of the original chemical equilibrium of a water molecule which comes in contact with the substance in question, but without necessarily breaking up the water molecule and effecting an actual union of either of its constituents with the attracting substance. This results, according to Schönbein, in a state of polarization of the molecules of the liquid and metallic elements composing the cells, which continues so long as the metal—say zinc—remains in contact with the water. The essential difference between the views of Schönbein and the supporters of the contact-theory is that he places the seat of the electromotive force entirely in the contact of the zinc and the water, and finds the force itself in the chemical attraction which the zinc exerts on the oxygen of the water; while the contact-theorists place it at the contact of the zinc with the platinum, and wholly ignore the chemical relations of the zinc and the platinum with the constituents of the water.

In reply to an objection raised by Pfaff, that the supposed power of polarization in the molecules of the metals is quite incompatible with their conducting power, Schönbein quotes with approbation Faraday's exposition of the process of conduction in general, which he summarizes as follows; "Conductivity of a body is synonymous with electrical polarizability of its particles, and the conduction of electricity through a body I consider as two actions occurring indefinitely near each other in time; namely, the polarization and depolarization of the arranged particles of a body, in which the first of necessity precedes the second."

Schönbein considers the objection of the contact-theorists that when two metals, say zinc and platinum, are placed in contact and in some electrolytic liquid containing oxygen, they exhibit sensibly the same difference of potential, whether the liqnid be water or an aqueous solution of sulphuric acid, nitric acid, caustic potash, etc. Since these liquids act on the metals in widely different ways when the circuit is open, while the difference of potential is nearly the same with them all, it follows, say they, that the seat of the electromotive force must be looked for at the metallic contacts, and not at the junction of the metals with the liquids, and hence the chemical theory cannot be true.

It is easily seen that this fact does not make against, but, cn

the contrary, it supports the chemical theory. For the magnitude of the electromotive force is measured by the difference in degree of the oxidizability of the two metals; or, more accurately, is equal to the difference in the chemical attraction of the two metals for the oxygen of the electrolyte. It makes no difference whether the metals exercise their attraction towards the oxygen in combination with acid, alkali or other substance in solution; the difference of these attractions remains the same, and so the electromotive force remains unaltered.

That the same two metals, joined up in circuit with different electrolytic liquids containing oxygen, give rise to different intensities of current, however, is explained naturally, as in the contact-theory, through the different conducting powers of the different liquids. Schönbein thinks the contact-theorists in error, in that they cannot see chemical action as electromotive force, and that the supporters of this chemical theory deceive themselves when they assume that the disturbance of the electrical equilibrium of an open or closed circuit must always precede an act of chemical combination, and that the *actual* chemical effect is but cause of the current.

Schönbein's reasons for adhering to his own view may be briefly stated: because the contact hypothesis must ignore all chemical relations of the matters which enter into the composition of a battery. While, on the other hand, experiment shows that in all cases observed an intimate relation exists between the voltaic phenomena and the chemical relations in question:—because it can always be predicted with certainty, from the chemical relations of the constituents of a battery, in what sense its tension or polarization will be, consequently, in what sense its current will flow when it is closed, while the contact hypothesis has no such advantage:—because, for the purpose of explaining the voltaic phenomena a new force is evoked, whose magnitude of action stands in no determinate relation to the magnitude of the matters in which it is supposed to operate,—a force, therefore, of which is demanded continuous work without being exhausted; while, on the other hand, the chemical theory employs a force already known by other effects, operating by well-known laws to produce the phenomena of the voltaic combination. Schönbein concludes his memoir from which condensed account is taken, by stating that he has a most lively conviction that he is very far from having given a full and complete theory

of the voltaic phenomena, for he sees only too clearly that it will be impossible to speak with seriousness of the establishment of such a theory before the nature of electricity and its relations to chemism are infinitely better known and more thoroughly explored.

That some difference of potential is due to the mere contact of different metals seemed to be established from the labors of the earlier workers; but the matter no longer admitted of question after the demonstration of Sir William Thomson with the divided disc. Thomson's teaching is not at all doubtful, and is well known to all. Maxwell points out the futility of any attempt to reach a satisfactory result by electroscopic methods. We need not dwell on the views of these two most distinguished electricians, since they are so well known through the text-books.

The laborious investigations of Ayrton and Perry have confirmed the truth of the law, that the sum of the differences of potential at the various junctions is equal to that at the poles of the open combination; but they decide nothing further.

One of the most interesting discussions of the question is that of Pellat. Let $V—V_1$ represent the difference of potential between metals in contact and in electrical equilibrium. Let Q be the amount of electricity which traverses the joint. Then, $Q\ (V—V_1)$ will be the work done, and there will be a certain amount of heat absorbed or set free. Hence, it would seem to determine the electromotive force in absolute measure from calorimetric data. The determination so made, it may be thought, should agree with that observed electroscopically. But, as a matter of fact, the result obtained by the latter process is many times greater than that obtained by the former. The error lies, apparently, in the assumption that no other than electric forces can do work on electricity in motion. In the case of two metals in contact and in electrical equilibrium, there is no reason for supposing a sharp transition from potential V to potential V_1. There is, no doubt, an exceedingly small layer of transition between them in which the change occurs. In this layer unit electricity is solicited to move in one sense by a force $\frac{dv}{dn}$; but as it remains at rest, there must be another equal force acting in the opposite sense.

If, now, on suitably closing the circuit, the current pass, there will be two works of opposite sign, to the difference of which the Peltier effect corresponds.

The quantity to be measured is the difference of potential in the two layers which cover the two metals in contact and in equilibrium. This may be called, "Difference of apparent potential."

Pellat finds that this depends upon the nature of the surfaces and varies with the chemical and physical changes which the surfaces undergo. He found that when the air or gas surrounding the metals is rarefied, the difference of potential is increased, and that it returns to its normal value more slowly than the pressure returns to its normal value.

This points, evidently, to some change in the metallic surfaces dependent on the change of pressure, but requiring longer time. To directly determine whether the apparent difference of potential of two metals, in contact in air and in equilibrium is the same as the electromotive force of a battery element formed of the same two metals and a liquid, difficulties which seem insurmountable arise. The same surfaces of the metals, which are employed for measuring the apparent potential in air, should be employed with the liquid of the battery element; and, moreover, the liquid should be one which does not act on the the metals. Such liquids being unknown, Pellat employed alcohol as being approximately fit; and by observing the changes which occurred at given intervals of time he drew the curve of change, and by exterpolation found the difference of potential at the instant of contact, and therefore before any change had occurred. The result is that the apparent difference of potential has the same value as the electromotive force of the battery element formed by alcohol and the same two metals, not yet altered.

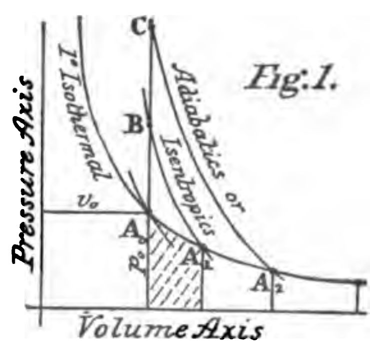
It will be noted that I have refrained from expressing any decided opinions respecting the question under consideration. My object is to bring before you somewhat briefly the course which the treatment of the matter has taken.

PAPERS READ.

ENTROPY AS A PHYSICAL QUANTITY. By Prof. J. BURKITT WEBB, Hoboken, N. J.

[ABSTRACT.]

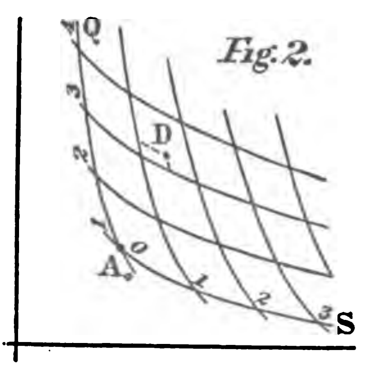
THIS paper attempts to render the conception of entropy more familiar by showing that we are accustomed to similar ideas in every-day matters, and that in thermodynamics the realization of its signification is no more difficult than that of energy. With physicists, especially, the latter term is used with great frequency and freedom, but the ordinary student rarely ventures upon the former. We are accustomed to consider the value of a thing for our purposes as depending not only upon its value *per se*, but upon its location, condition and other attendant circumstances. One example of this analogy will suffice: There is the same intrinsic value for food in grass and baled hay; and yet the former, or even loose hay, will not bring as much in the market owing mainly to the excessive space which it occupies. The same thing holds good in thermodynamics: For use as a working fluid in a heat engine, common air, or other gas, is more or less valuable according to the space which it occupies. The advantage of the steam over the air engine arises mainly from the fact that a pound of water occupies very much less space than a pound of air; indeed, if water existed at ordinary temperatures in the gaseous form, it would be useless for most of the purposes of life. In an air engine, the conversion of heat into work is necessarily accompanied by an expansion of the air, which becomes on that account less and less useful until it must be recompressed to be used further, and in a steam engine the same is true, condensation taking the place of compression.



To render the conception of entropy more precise, we will use the ordinary pressure and volume diagram Fig. 1, in which is represented the isothermal corresponding with a uniform temperature τ_0, which we will suppose prevails in all surrounding bodies. We will further suppose (for simplicity) that $\tau_0 = 1°$ absolute temperature. On this isothermal let A_0 represent the condition of a pound of perfect gas, whose temperature, pressure and volume will be respectively, τ_0, p_a and v_a; we may consider A_0 as the starting point from which to measure entropy, so that at A_0 we have Φ or $S = O$, Φ being the

symbol used by Rankine, while S is used by Clausius, the originator of the name entropy. Now suppose this pound of gas to be in an engine and that we furnish heat from some source slightly hotter than 1°, the gas will expand isothermally and do work. When one foot-pound of heat has been thus converted into one foot-pound of work, let A_1 represent the condition of the gas. The shaded area represents a foot-pound of work. After expanding the gas to A_1, if it be practically possible to expand it only to a volume corresponding with A_{0}, we have used up one-tenth of our available expansion; another tenth used brings the gas to A_2, etc., etc. In this case, considering entropy to increase to the right, we shall have at A_0, A_1, A_2, etc., the entropy of the gas equal successively to 0, 1, 2, etc., which way to count entropy, whether it shall increase to the right or left, is of not so much consequence. As we have represented it it indicates the amount of expansion, or of conversion of heat into work, from an assumed zero or starting point. Counted in the opposite direction it would simply indicate the converse, that is, the amount of compression, or of conversion of work into heat; in fact it might seem more natural to suppose the starting point to correspond with infinite volume and the entropy to be the amount of mechanical work converted into heat by compressing the gas into a compact and useful form; but this would give us infinite values for the entropy so that a zero point within reach is more practical. While we may indicate the state of the gas by means of its pressure and volume, in many thermodynamic problems it can be done in a much simpler way by means of entropy.

Consider in the second place that the gas is heated from A to B and C. While the heat energy is locked up in the fuel it loses nothing, but as soon as the fuel is burned (as when the gas explodes in a gas engine) the heated air or gas must be, or considered to be, immediately expanded down to the prevailing temperature τ_0, or heat will be wasted by conduction and radiation to surrounding bodies; therefore if C has been so chosen that CA_2 is an isentropic, adiabatic, or curve of no transmission of heat, representing the expansion of the gas with no outward gain or loss of heat, except that heat which by the expansion of the gas is converted into work, —if CA_2 be an adiabatic then the entropy of the gas at C is the same as at A_2, or entropy = 2. In the same way the entropy along BA is 1; along CA_2, 2; along DA_3, 3; etc.



Instead, therefore, of dividing the diagrams into squares by lines parallel to the rectangular axes, thus representing equal increments of volume and pressure, we may use the coördinates of energy, Q, and entropy, S, to express the condition of the gas. According to this system (see Fig. 2)

we take the 1° isothermal as the axis of entropy and the adiabatic through A_0 as the axis of energy, or Q. Coördinate axes need not be straight lines and here they are hyperbolas. From A_0 as a zero point we number the axis A_0S for the successive values of S. To mark the values of Q along A_0Q, we must assume as a unit, say, the value of Q at A , then at A $Q =$ 1, and Q increases as shown in the figure. For example, the coördinates of the gas at D will be $Q = 3.2$, $S = 1.5$. The energy so expressed will evidently not be in foot-pounds but in some multiple thereof, and the successive isothermals through 1, 2, etc., must be drawn, *i. e.*, these points must be chosen, so that they shall indicate increments of heat energy equal to the amount contained in the gas at A . It may be added that entropy should be regarded, like color and some other properties, as being independent of the quantity of the substance so that the entropy of two or more pounds is no different from that of one pound, being measured by the work-done per pound of gas along a standard isothermal. If we are dealing with an imperfect gas, part of the work done in expanding will be internal work, so that the ordinary volume and pressure diagram will not show it; we can, however, cover both cases by expressing the entropy in terms of the heat furnished (expressed in mechanical units). The entropy then at any point on the τ_0 isothermal equals the heat furnished in expanding from A_0 to that point; for heat furnished during expansion along any higher isothermal, we have to remember that the amount of heat converted into work is in proportion to the temperature of the expansion, therefore in any infinitesimal change in the condition of the gas the change of entropy equals the heat furnished divided by the absolute temperature at which it is furnished, and for any finite change we have simply to sum the infinitesimal elements composing it The entropy then at any point will equal the sum of all the elementary portions of heat furnished the gas in changing it from the condition A to the point in question, each portion being divided by the temperature at which it is furnished, and the change may occur along any path whatever.

RANKINE'S THERMODYNAMIC FUNCTION Φ. By Prof. J. BURKITT WEBB, Hoboken, N. J.

[ABSTRACT.]

IN an address on Rankine's Second Law of Thermodynamics, read last year before section D, mathematical explanation of the subject was avoided and the promise made that it should follow; this paper is a contribution in that direction.

On page 312 of the "Steam Engine," Rankine gives the following formula

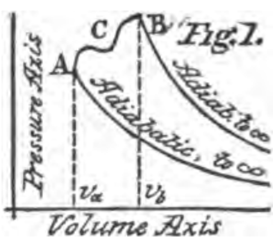
$$\text{“}dH = \tau d\Phi = \left(k + \tau \int_{\infty}^{v} \frac{d^2p}{dt^2}\,dv\right)d\tau + \tau \frac{dp}{dt}\,dv \qquad (2)\text{”}$$

where dH is the quantity of heat (expressed in mechanical units) necessary to heat one pound of a gas by $d\tau$ while it expands through dv. Φ is Rankine's thermodynamic function, also called entropy. I propose to deduce this formula directly from fundamental principles, which will at the same time make clear the exact meaning of all its parts. For convenience let

$$dH = kd\tau + d_\tau H + d_v H + d_0 H,$$

where k is a constant and defined to be the quantity of heat required to heat a pound of gas through 1° when the gas is in an infinitely expanded state; and where the subscripts τ, v and 0 indicate respectively internal work done while the temperature is raised, internal work done when the volume is increased, and external work done.

We need, first, a proposition with respect to external work; see "Theorem," page 303, which we shall explain in a different way.



In the ordinary volume and pressure diagram, Fig. 1, let ACB be a curve representing the manner in which the pressure changes, with respect to the volume, as heat is furnished to the gas.

Suppose first that the gas were to expand from A to ∞ along the lower adiabatic; the heat (or kinetic energy) existing in the gas at A will be expended, partly in doing internal work (say, in overcoming molecular attractions) the amount not needed for this, performing the external work $\infty A\, v_a\, \infty$. Now, let heat be supplied in such manner that the gas shall follow the path ACB to B, and then be expanded adiabatically to ∞. We shall thus obtain an increase of the external work by the quantity $\infty ACB\infty$, but the internal work will be the same whether we expand along the line $A\infty$ or along $ACB\infty$, because the internal work done along a path must be a function of the condition of the gas at the two ends of its path; or, more exactly, it will be a function of the state of the gas (say the volume and pressure) at the end of the path minus the same function of its state at the beginning of the path. For this reason no attention need be paid further to the internal work; it will be taken care of by the heat which is in the gas at A. The truth of the proposition stated by Rankine is now clear, for it follows from the above and the "first law" that the heat furnished along the path ACB is exactly equal to the increase of external work $\infty ACB\infty$.

To find now the value of $d_v H + d_0 H$, put p = external pressure, $p_v = \frac{d_\tau H}{dv}$, the representative or average internal pressure, also $p_1 = p_v + p$; then $d_v H + d_0 H = p_1 dv$, and we must find p_1.

Rankine's second law enables us to do this (see p. 306, *et seq.*). In Fig. 2, let the differential change to be considered be from A to B', which we may separate into the isothermal expansion AA' and the increase of temperature $A'B'$, and consider now the former alone. An expansion AA' will, according to the proposition proved, require the heat $\infty AA' \infty$, while an expansion $ABB'A'$ will require $\infty ABB'A' \infty$, *i. e.*, it will require the increased amount $ABB'A'$, all of which will appear in external work. Therefore, in "consequence of the presence," as Rankine's puts it, of the additional increment of temperature $d\tau$, or, as put in the address referred to, in consequence of an additional increment of agent-energy in the gas, there is done the additional increment of work (all external) $dpdv$.* Now, the second law gives the proportion

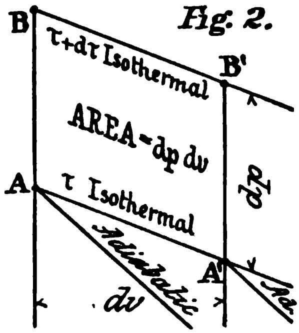


Fig. 2.

$d\tau : dpdv :: \tau : p_1 dv$, the whole work due to the change dv,

from which $p_1 dv = \tau \frac{dp}{d\tau} dv = d_v H + d_0 H$,

also $\qquad p_1 = \tau \frac{dp}{d\tau}$ or $\frac{dp}{d\tau} = \frac{p_1}{\tau}$.

Let us now consider the quantity $\frac{dp}{d\tau}$ which is the total pressure, per unit of temperature, which acts to produce increase of volume. If the gas be perfect, there will be no molecular attraction, and $\frac{dp}{d\tau} = \frac{p_1}{\tau}$ is a constant, and, further, $p_1 = p$, but for imperfect gases $\frac{dp}{d\tau} =$ variable.

Consider now the equality of the internal work done along the two paths AA' and $ABB'A'$ and we shall see that if the internal work along AB is greater than that along $A'B'$, then the internal work along BB' must be less than that along AA', by the same amount. We may ascertain the amount of this difference by subtracting the difference of the external works along AA' and BB', and which $=$ the area $ABB'A'$ from the corresponding difference of the total works.

Thus:—

Total work along $BB' = (p_1 + dp_1)\, dv$

" " " $AA' = p_1 dv$.

Increase of total work for BB' over $AA' = dp_1 dv$.

Increase of external work for BB' over $AA' = dp\, dv$.

Increase of internal work for BB' over $AA' = (dp_1 - dp)\, dv$.

* dp and dp_1 are to be understood as the partial differentials with respect to τ, that is, as equivalent to $\frac{dp}{d\tau} d\tau$ and $\frac{dp_1}{d\tau} d\tau$.

But $p_1 = \tau \frac{dp}{d\tau}$, therefore

$$dp_1 = d\left(\tau \frac{dp}{d\tau}\right) = d\tau \frac{dp}{d\tau} + \tau \frac{d^2 p}{d\tau} = dp + \tau \frac{d^2 p}{d\tau^2} d\tau$$

Therefore

$$(dp_1 - dp)\, dv = \tau \frac{d^2p}{d\tau^2}\, d\tau\, dv,$$

or the internal work along BB' will be less than that along AA by the quantity $-\tau \frac{d^2p}{d\tau^2} d\tau\, dv$, which will, therefore, be the excess of $d_\tau H$ for AB over $d_\tau H$ for $A'B'$.

Let the differential area of Fig. 2 be now extended out to ∞ at the right, then will the value $d_\tau H$ be equal to the decrease of internal work for $B\, \infty$, as compared with $A\, \infty$, because Rankine supposes $d_\tau H = 0$ at ∞, or

$$d_\tau H \doteq -\tau d\tau \int_v^\infty \frac{d^2p}{d\tau^2} dv = \tau d\tau \int_\infty^v \frac{d^2p}{d\tau^2} dv$$

Substituting these values we obtain the formula (2) given by Rankine, from which formula (1) may be obtained by integration.

POLARIZATION OF RESISTANCE COILS. By Prof. T. C. MENDENHALL, Washington, D. C.

[ABSTRACT.]

IT is not known that attention has hitherto been called to the fact that many resistances — most notably those of high values — take upon themselves a charge when connected with a battery, behaving very like a secondary battery or a "soaking" condenser (such as a submarine cable) and that the results of measurements made by means of such coils may be greatly in error on account of such charge. Examples are given, and the attention of electricians is invited to the subject.

ELECTRIC THERMOMETRY. By Prof. T. C. MENDENHALL, Washington, D. C.

[ABSTRACT.]

A DESCRIPTION of improvements in methods of determining the temperature of a distant point by means of electricity as developed in the Physical Laboratory of the U. S. Signal Service during the past year or two.

A modification of Siemens's method by resistances, or of the bolometer of Langley, has been used and is made practicably applicable to air, water or earth's temperatures.

The differential resistance thermometer is also used in the system. An electric air thermometer is shown with charts, showing comparison with mercurial standards.

REPORT OF PROGRESS IN THE STUDY OF ATMOSPHERIC ELECTRICITY. By Prof. T. C. MENDENHALL, Washington, D. C.

[ABSTRACT.]

A BRIEF résumé of the results of the study of atmospheric electricity by the U. S. Signal Service during the past year. Improvements have been made in the instruments used, and the question of exposure of collectors has been entered into. Five or six special stations for observation have been established, and simultaneous observations have been made during different periods of time. Charts exhibiting the results of these observations accompany the paper and some conclusions are stated, which seem to be justified by the facts as thus far known.

EARLY TELEPHONIC APPARATUS. By Prof. A. E. DOLBEAR, College Hill, Mass.

[ABSTRACT.]

THE paper calls attention to the published descriptions of telephonic apparatus before 1876, with special reference to details of structure. In the transmitter, of the vibrating disk carrying electrodes of different substances, of the induction coil, also of a magneto-electric transmitter; in the receiver, of the eleotro-magnet and disk armature, of the electro-magnet as pole piece for a permanent magnet and also a description of the thermo-telephone.

A NEW DETERMINATION OF THE RELATIVE LENGTHS OF THE IMPERIAL YARD AND OF THE METRE DES ARCHIVES. By Prof. WM. A. ROGERS, Cambridge, Mass.

[ABSTRACT.]

THE present determination consists in a comparison of a half metre with a half yard upon bars of glass, of steel and upon aluminum bronze. Each of these standards has been compared with the two halves of my standard metre and standard yard upon steel, whose relations to the imperial yard and the metre des archives are known. The peculiarity of his method consists in such an arrangement of the graduations that the length of the half metre can be read off in terms of the extension of the half yard as a vernier.

The following equations represent the result of previous investigations,

First series $Y_0 + 3.37015$ inches $= A_0$

Second series $Y_0 + 3.37025$ inches $= A_0$

Third series $Y_0 + 3.37020$ inches $= A_0$

A note accompanied the publication of the last result to the effect that the value 3.37027 is undoubtedly too great, but that the true value could not fall much below 3.37015; the value first announced. The present discussion yields the equation:

$$Y_0 + 3.37012 \text{ inches} = A_0.$$

DESCRIPTION OF A COMBINED YARD AND METRE WHICH WILL BE USED BY THE DEPARTMENT OF STANDARDS OF THE BRITISH BOARD OF TRADE IN A DEFINITIVE DETERMINATION OF THE RELATIVE LENGTHS OF THE IMPERIAL YARD AND OF THE METRE DES ARCHIVES. By Prof. WM. A. ROGERS, Cambridge, Mass.

[ABSTRACT.]

DESCRIPTION as indicated by the title. Two standards have been constructed, one upon Baily's metal and one upon a lamina of gold inserted in a bar of aluminum bronze. The form of these standards will be illustrated by a combined half yard and half metre upon a gold surface.

A STUDY OF THE IDIOSYNCRASIES OF MERCURIAL AND METAL THERMOMETERS. By Prof. WM. A. ROGERS, Cambridge, Mass.

IT appears from my observations that standards of length, in which the metals employed have widely different coëfficients of expansion, apparently vary in length from a constant relation according as the comparisons are made during the winter or the summer months.

It is the object of this paper to ascertain if these deviations can be explained by the irregular and abnormal indications given by the thermometers employed to measure the temperatures. The observations have continued from December 1885 to August 1886. The following is an outline of the discussion.

(*a*) Description of thermometers.

(*b*) Description of comparing room.

(*c*) Methods of observation.

(*d*) Normal relations between the different thermometers compared.

(*e*) Probable errors of reading under normal conditions.

(*f*) Enumeration of the idiosyncrasies discovered and enunciation of the law under which slow changes of temperature occur as indicated by mercurial thermometers.

S. H. M. HYPOTROCHOID. By Prof. I. THORNTON OSMOND, State College, Pa.

[ABSTRACT.]

THE importance of simple harmonic motion in physics calls for a simple and efficient instrument to realize its definition and demonstrate its elements to the student.

The equations of the hypotrochoid, $x = (R - r) \cos A + r \cos \frac{R-r}{r} A$, $y = (R - r) \sin A - r \sin \frac{R-r}{r} A$, suggest the construction of such an instrument. If $r = \frac{1}{2} R$, then $x = R \cos A$, $y = 0$, and the hypotrochoid is a straight line described with S. H. M.

This instrument, accurately constructed, gives very exact S. H. M., and permits very careful study of the velocities and accelerations along the path; may be used to show the S. H. M. character of pendulum motion, elastic vibration, oscillation of liquids, etc.; for tracing directly or for plotting from measurements on it, the S. H. M. curve and others; for demonstration of several propositions in the composition of S. H. motions; and by a very slight change of the position of the point it gives examples of elliptic harmonic motion.

OBSERVATIONS ON THE FORMATION OF DEW. At Houghton Farm, Mountainville, Orange Co., New York, summer of A. D., 1884. Read by HENRY E. ALVORD, C. E.

[ABSTRACT.]

As a work of verification and further inquiry, rather than of original investigation, observations upon the formation of dew were made during the summer of 1884, by persons connected with the experiment department of Houghton Farm.

The first question proposing itself was concerning the relation between the temperature of the lower strata of the air and the upper strata of the soil, at times most favorable to the formation of dew. The manner of observation was somewhat similar to that in the famous experiments of Dr. Wells. On a moist, grassy meadow, thermometers were exposed, one at a height of four feet, and one at four inches above the ground. Another instrument was thrust into the grass and rested upon the surface of the soil and another was placed at a depth of three inches in the soil; the four were nearly in a vertical line. The thermometers were long bulb, stem graduated, made by Green, verified at New Haven, and reading to tenths of a degree F. The grass was kept cut to a length of two or three inches. A second similar set of thermometers was placed on soil kept free of all vegetation. All were read at 7 and 9 P. M. from May to October, inclusive; and about once in every ten days during this time, when a favorable night occurred, hourly observations were made, from sunset until sunrise. Other thermometers than those described were placed in various positions and read for considerable periods, some during the entire season, for verification of those in the regular sets.

In connection with these observations, and as bearing upon the same subject, a very satisfactory investigation was conducted upon the transpiration or exudation of water, during the night, by plants of various kinds, including measurements of the quantity of water thrown off by plants. Apparatus was used similar to what has been described by Sachs and Darwin, and the "Potétomètre" of Dr. J. W. Moll.[1] This comprised several hundred observations on seventy-six different nights during the season of 1884, besides the arrangement of the apparatus.

The following facts were noted as the result of the observations made:—

1. A clear sky and a calm atmosphere were always favorable to dew formation.

2. In proportion to the extent of these favorable conditions, the temperature at four inches above ground was lower than at four feet above, over both turf and bare soil. In rainy or cloudy weather, the two thermometers showed little or no difference; on clear, calm nights, the lower would indicate ordinarily about 5° F. lower temperature and occasionally the difference would be as much as 10° F.

3. With the same conditions favorable to dew formation, the thermometer, resting upon the surface of the soil in the grass, always indicated a higher temperature than the one four inches above it. The excess was usually from 10° to 15° F. and sometimes as much as 20° F. This difference, within so short a distance, is quite remarkable and at first seemed almost incredible, but repeated observations thoroughly established the belief that here was the critical dew-forming stratum.

On bare soil the difference between the corresponding strata was less, but still existed, the surface thermometer on the whole registering the higher temperature.

4. The temperature three inches below the surface of soil was always higher than that at the surface itself, and consequently considerably higher than that of the air four inches above the soil.

5. There is an exhalation of moisture from the earth at night, constant, although of course varying in degree.

6. Most of the moisture seen upon many plants in the morning, in the course of a season, is transpired by the plants themselves, and this transpiration is sufficient in quantity to supply an appreciable portion of the atmospheric vapor, subsequently deposited as dew.

From these facts, established by repeated observations, it appears that the lower stratum of air rapidly increases in cold as we descend toward the ground, until checked by the radiation of heat stored up there during the day.[2] The height of this critical stratum, where the two temperatures just counteract each other, varies under different conditions. On bare soil, it is usually very near the surface and even may be slightly below it. Grass, or other thick growths of vegetation, behaves like the soil, in retaining a considerable degree of heat in the air entangled among its foliage, so that its presence restrains the cold stratum of air at a still greater height.

[1]See Nature, Vol. 30, pp. 7 and 79.
[2]See Dr. Wells' Essay on this point.

We have, therefore, on the occasions when dew is formed most copiously, a stratum of air of markedly low temperature, lying close down to the surface of the ground, with its lower limit sharply defined, but above, gradually increasing in temperature. Above this stratum is the comparatively warm atmosphere, bearing watery vapor; below it, a thin layer of air supplied with heat and moisture from the soil. The result is the formation of dew by condensation of watery vapor within the cold stratum.

To maintain that dew results entirely from the watery vapor of the atmosphere, as some have done, is irreconcilable with the facts observed. Neither do they support the claim that moisture arising directly from the earth is the only source of dew. It is undoubtedly derived from both sources, in proportions varying under different conditions. Dew depositions upon bodies near the ground are very generally formed from watery vapor arrested as it rises from the soil. It is reasonable to conclude that a greater part of this moisture is condensed while near the surface of the ground, and therefore the dew deposited upon objects at greater height, except plants from which the moisture of transpiration is similarly condensed, is derived from the vapor in the general atmosphere. Again, the relative humidity of the warm air arising from the earth may greatly exceed that of the general atmosphere; or, to express it in another way, its dew point may exceed the temperature of the cold stratum, far more than that of the general atmosphere does, and consequently the absolute amount of the moisture withdrawn from it by condensation will be greater. We believe such a condition frequently occurs and is perhaps the strongest argument in support of the statement that the soil moisture supplies much the larger part of what we call dew. Dr. Wells maintained an opposite view, but still acknowledged the influence of soil moisture in dew formation. Professor Stockbridge declared that dew was caused by the condensation of moisture rising from the soil.[1]

From our observations upon the relative temperatures of different strata of air and soil, we believe both gentlemen were wrong and both were right, in so far as that dew may be derived exclusively from either air or soil moisture, or from both (as also partially from plants) according to varying conditions.

It was early impressed upon us, that while some students of dew formation had observed it in its relation to the air, and others in connection with the soil, and still others had studied the transpiration of plants, no one investigator was recorded as using the three factors at once, and yet in no other way could the phenomenon be satisfactorily explained. In this essential particular, these observations differ from older records, and so, while generally going over ground well trodden, we may have succeeded, by these deviations, in confirming conclusions of others, which have heretofore appeared antagonistic.

Attention is invited to the fact that these observations were made, the record completed and this manuscript first prepared, during the year 1884, twelve months before the publication of similar observations by Mr.

[1]Investigations on Dew, etc., 1879.

Aitken, by him presented to the Royal Society of Edinburgh on the 21st of December, 1885.

These observations were planned and executed by Winthrop E. Stone, B. S., Mass. Agrl. Coll., 1882, and Frank E. Emery, B. S., Maine State Coll., 1884, as part of their duties in the experiment work of Houghton Farm. The report was originally prepared by Mr. Stone. It is transcribed from the records for present use by Henry E. Alvord, manager of Houghton Farm.

Determination of capillary constants. By W. F. Magie, Princeton, N. J.

[abstract.]

1. Discrepancies in the values for surface tension and for contact angle obtained by different methods of measurement.

2. This possibly due to variations in the contact angle as claimed by Quinche.

3. Effect of such variation on the Laplacian theory of capillarity.

4. Measurements hitherto made by me and apparatus prepared to test the question of the discrepant values.

On a method of counteracting the effect of change of level of the torsion balance. By Wm. Kent, Jersey City, N. J.

[abstract.]

In the ordinary form of the torsion balance used as a weighing machine, any change of level of the base of the balance throws the center of gravity of the supported poise out of its normal position (vertically above the axis of rotation) and causes the beam to tip. To counteract this effect, which is undesirable in fine balances, Dr. Alfred Springer devised the system of using two poises, so placed that the gravitating action of one neutralizes that of the other. The writer has devised a modification of the system, in which the secondary poise is attached, not to an independent support, but to a moving part of the balance. In both of these systems a secondary beam may be attached to the secondary poise standard, which may be made to rotate through a larger angle than that of the primary beam, and so act as a multiplying index.

On the application of a mirror to the multiplication of the indications of a torsion balance. By Wm. Kent, Jersey City, N. J.

[abstract.]

The paper first shows that multiplication of the indications of the primary scale beam, which is inapplicable in fine knife-edge balances, on account of the friction of the knife-edges, is very desirable as well as practicable in torsion balances, in which any load, however small, will cause some motion, although the extent of that motion may not be visible to the naked eye. Two methods of using a mirror to magnify the

apparent motion are described. In one, a lantern throws a ray of light against a convex mirror attached to a moving part of the balance, which reflects the ray on a graduated plate. In the other, a concave mirror is placed in the rear of the index pointer of the balance, an eye-piece being placed in front of the pointer, through which the operator views the reflection of the pointer in the mirror. A slight movement of the pointer causes a large displacement of its reflection in the mirror.

ON THE TIME OF CONTACT BETWEEN THE HAMMER AND STRING IN A PIANO. By Prof. C. K. WEAD, Malone, N. Y.

AN account of some experiments to measure the time of contact between the hammer and string. This time is found for the lowest C to be from one-sixth to one-fifth of the time of vibration[1] according as the blow is hard or light.

UPON THE INCREASE OF TORSIONAL ELASTICITY OF METALLIC WIRES. By Prof. WILLIAM A. ANTHONY, Ithaca, N. Y.

[ABSTRACT.]

THE elasticity was determined from the time of torsional vibration of a cylindrical mass of eleven kilos attached to the wire by a clamp that brought the wire accurately into the axis of the cylinder. The arc of vibration was usually about twenty degrees and the time was determined from a record automatically produced on a chronograph. Wires of steel, brass, phosphor bronze, aluminum-bronze and "aluminum silver" were experimented upon. For all these except phosphor-bronze the arc of vibration diminished rapidly, and the period diminished rapidly with the arc. For phosphor bronze the period was almost constant for wide difference in arc, and the decrement of arc was far less than for the other wires. For this reason, only the experiments with phosphor bronze have been fully discussed.

The results are as follows:—A wire that had been sometime drawn diminished in period in the first twenty-four hours about .03 of one per cent and for the next three days remained nearly constant.

A wire of .9 mm. diam. was drawn down to .69 mm. and immediately subjected to test. The times of vibration of the mass, corrected for temperature, for the four days of the experiments were as follows:

TIME. Days.	PERIOD. Seconds.	DIFFERENCE.
0	9.5748	
1	9.5442	.0304
2	9.5332	.0110
3	9.5278	.0054
4	9.5252	.0026

[1] This paper appeared in the American Jour. Sci., Nov., 1886.

A piece of the same wire that had been hanging loose for these four days was now put under test with the results as follows:

TIME. Days.	PERIOD. Seconds.	DIFFERENCE.
0	9.5226	
1	9.5158	.0068
2	9.5133	.0025
3	9.5118	.0015
4	9.5102	.0016

A wire that has not been under tension increases in elasticity, therefore, almost as fast as one that has been in use.

Another wire that has been in use for torsional experiments for nine months is still diminishing in period about .02 of one per cent per month.

Physical Laboratory, Cornell University, August, 1886.

ON A METHOD OF REGISTERING SMALL VARIATIONS OF SPEED, AND DETERMINING THE ABSOLUTE NUMBER OF REVOLUTIONS OF AN ENGINE OR OTHER RUNNING MACHINERY. By Prof. WM. A. ANTHONY, Ithaca, N. Y.

[ABSTRACT.]

SPEED-COUNTERS give only the total number of revolutions in a given period. Speed-indicators must be calibrated, and are seldom reliable within one or two per cent. When a steam engine is under test, or when dynamos are used for experimental purposes, it is desirable to have a continuous record of the speed, of such a character that small deviations from the normal rate shall be plainly indicated. The method which it is the object of this paper to describe may be best understood by supposing the engine, or other machine, whose speed it is desired to record, to take the place of the driving mechanism of the ordinary cylinder chronograph used for astronomical purposes. The engine may be so geared to the cylinder that the latter shall, when the engine is running at its normal speed, make one revolution per minute, or one revolution in any whole number of seconds, as may be desired. It is evident that, if the engine run continuously at its normal speed, the notches indicating the seconds in the chronograph record, will form straight lines parallel to the elements of the cylinder. If the speed vary from the normal, these lines will form an angle with the elements of the cylinder and this angle will change for every variation in the speed.

Let $c =$ circumference of the cylinder.

$d =$ longitudinal movement of pen for one revolution of cylinder.

$a =$ number of revolutions of engine to one of cylinder.

$x =$ number of revolutions of engine per minute.

Suppose the clock to make a record every two seconds, and let these records fall in n lines on the chronograph sheet. If these lines make with

the elements of the cylinder an angle θ, a point on the circumference of the cylinder moves in the time that elapses between a given record and the next in the same line, a distance $c + d$ *tang* θ. Hence the distance traversed in one second is

$$\frac{c + d \times tang\ \theta}{2n} = \frac{xc}{60a}.$$

Hence

$$x = \frac{30a}{n}\left(1 + \frac{d}{c} tang\ \theta\right).$$

If θ is zero

$$x = \frac{30a}{n}.$$

Represent this value, which was assumed as the normal speed of the engine, by b, then

$$x = b\left(1 + \frac{d}{c} tang\ \theta\right)$$

$$\text{and } x - b = \frac{db}{c} tang\ \theta.$$

Putting $x - b = 1$, we may find the value of θ' corresponding to a change of one revolution in the rate of the engine.

$$tang\ \theta' = \frac{c}{db}.$$

As the apparatus was used at the Cornell University when the accompanying records were made, the values of the constants were as follows:— c, 21 3-4ths inches; d, 1-12th inch; b, 285 revolutions; a, 285; n, 30. The formula for x is, therefore,

$$x = 285\ (1 + .00383\ tang\ \theta).$$

The angle θ' corresponding to a variation of one revolution from the normal speed is

$$tang^{-1}\theta' = .9158, \text{ about } 42\tfrac{1}{2} \text{ degrees.}$$

It is plain from the above that the sensitiveness of the instrument is increased by making c large or d small.

The indications of the instrument are not changed by changing the relation between the speed of the cylinder and engine so long as that relation is such that the record appears in straight lines parallel to the axis of the cylinder for the same normal speed, b. This relation is only important when the speed of the engine is subject to rapid fluctuations. To show such fluctuations, the cylinder must be made to revolve rapidly, reducing the number n, of lines in the record.

This method of recording speed is especially valuable in connection with the modern high speed engines and with dynamo-machines where any considerable change of speed would be inadmissible. In constructing an apparatus expressly for it, the ratio of c to d might be made 100, when a change in speed of one per cent would be represented by an angle of forty-five degrees. In a shop or factory an apparatus might be improvised for

the purpose, by mounting a cylinder in a lathe and attaching the recording mechanism to the slide-rest.

Physical Laboratory, Cornell University, August, 1886.

RELATION OF DEW TO SOIL MOISTURE. By Prof. J. W. SANBORN, Columbia, Mo.

[ABSTRACT.]

THIS paper is the result of four years of investigation by direct and indirect tests of actual soil moisture at night and in the morning. The temperature of the soil, the water-bath test of the moisture by several systems, and direct weights of the soil by me in two states and under various states of the earth, all conspire to show that soil usually loses moisture at night. The amounts thus lost vary with the physical condition of the soil and humidity of the atmosphere. A gain is rarely made and then during dry time, and when the temperature of the soil falls to that of the air in immediate contact with the soil.

THE EFFECT OF WIND AND EXPOSURE UPON BAROMETRIC READINGS. By Prof. CLEVELAND ABBE, U. S. Signal Office, Washington, D. C.

[ABSTRACT.]

THAT the wind may have a mechanical effect on the readings of a barometer, whereby it fails to register the true static pressure of the atmosphere, is not a new suggestion, but the recent discussion of the subject seems to be entirely independent of the earlier writings.

As early as 1852, Col. Sir Henry James presented a paper to the Royal Society of Edinburgh containing the results of experiments demonstrating the actual occurrence of a mechanical effect, due to the wind on a barometer within a building as compared with one in the open air and explaining all the phenomena by their analogy to the effects of pressure and suction in the pneumatic experiments of Hawkesbee and Leslie.

The present writer calls attention to a device,[1] by which, for a given locality, the amount of the effect of the wind on the barometer may be measured and allowed for.

This device consists in the combined use of a Pitot tube (attached to a vane so that its mouth always faces the wind) and a simple vertical tube, exposed side by side above a house-top.

These tubes conduct to separate air-tight receivers, placed in a room below, in which aneroid barometers register, for the Pitot tube, a function of the atmospheric pressure *plus* the pressure of the wind; and for the straight tube, a function of the atmospheric pressure *minus* the effect of the suction of the wind.

After laboratory experiments have shown the relation of these two functions to each other, their combined use will furnish a simple means of eliminating the wind effect and obtaining the true static pressure of the atmosphere.

[1] Described in lectures delivered in Feb., 1882, of which an abstract is given in the Annual Report of the Chief Signal Office, 1882, p. 99.

A GRAVITY PARALLELOMETER. By J. A. BRASHEAR, Alleghany, Pa.

[ABSTRACT.]

THIS instrument has been devised to expedite measurements of deviation from parallelism in glass plates for optical purposes. It is not intended to take the place of optical tests, but is especially useful in the preparatory stages of the work.

A pendulum is suspended over a carefully prepared steel point which forms one of three such points that the glass plate is rested upon. This pendulum is delicately suspended on two conical pivots, and the upper arm of the pendulum is extended upward to a graduated arc, and is pointed so as to form an index to this arc. The whole pendulum system may be raised or lowered by a micrometer screw.

The plate being laid upon the three steel points, the lower end of the pendulum is brought down to the glass surface, and then by slowly rotating the plate, the thinnest part of it can readily be determined. When this part is found, it is only necessary to raise the pendulum system until the pointer indicates zero on the scale. A further rotation now determines the amount of error to be corrected. The two adjustable points may be set at any distance from the point under the pendulum so as to suit the dimensions of the plate being worked. Personal equation does not enter into the determinations of error, and very minute fractions of an inch may readily be discovered and marked for correction.

ON SOME NEW APPLICATIONS IN ELECTRICITY OF THE GRAPHICAL METHOD. By Prof. CHARLES K. WEAD, Malone, N. Y.

ILLUSTRATIONS OF MINNESOTA TORNADOES. By Rev. HORACE C. HOVEY, Minneapolis, Minn.

NOTE ON VARIATION IN RESISTANCE WITH TEMPERATURE OF CERTAIN ALLOYS. By Prof. BENJ. F. THOMAS, Columbus, O.

SOME NOTES UPON SUBJECTIVE AFTER-COLOR (COMPLEMENTARY COLOR). By CHARLES A. OLIVER, M.D., Philadelphia, Pa.

THE FIELD-MAGNETS OF A SELF-EXCITING DYNAMO MAY BE TOO SOFT. By W. L. HOOPER, College Hill, Mass.

ON A NAME FOR THE C. G. S. UNIT OF MOMENTUM. By Prof. C. K. WEAD, Malone, N. Y.

ON A SIMPLE ACCURATE METHOD OF REPRODUCING ETCHED SURFACES OF METEORIC IRONS FOR ILLUSTRATION. By GEORGE F. KUNZ, with Tiffany & Co., New York, N. Y.

ON A SINGULAR CASE OF DOUBLE REFRACTION. By DEWITT B. BRACE, Lockport, N. Y.

SECTION C.

CHEMISTRY.

ADDRESS

BY

HARVEY W. WILEY,

VICE-PRESIDENT, SECTION C.

THE ECONOMICAL ASPECTS OF AGRICULTURAL CHEMISTRY.

MEN of affairs often criticise science because it is not practical. Such a criticism is most unjust to science, and to those who make it, and who, on most subjects, display a degree of knowledge which such a remark does much to discredit. In point of fact, the material progress of the world has come far more from the researches of science than from the enterprise of business.

In responding to-day in the customary way to the honor of the presidency of Section C, which you have given me, I desire to say a few words respecting the economic aspects of Agricultural Chemistry, especially in the light of the progress in this branch of science made during the decade since our Association last met in this city.

The prosperity and advancement of a nation depend chiefly on its agriculture. The first and most insistent demands of a human being are for food and clothing, and for these he depends exclusively on the products of the field. In the United States alone, the carefully estimated mean annual values of agricultural products at the present time are:—

			Value.[1]
Wheat	450,000,000	bushels.	$140,000,000
Maize	1,900,000,000	"	627,000,000
Oats	600,000,000	"	168,000,000
Barley	60,000,000	"	33,600,000
Rye	25,000,000	"	14,000,000

[1] These values are based on the averages given in J. R. Dodge's Report, Dept. Agr., New Series, No. 25, pp. 13, 14, 15.

		Value.
Buckwheat	13,000,000 bu.	$7,280,000
Beef and veal (dressed)	4,000,000,000 lbs. at 9 cts.[1]	360,000,000
Pork (dressed) . . .	5,600,000,000 " 6 "	336,000,000
Mutton "	500,000,000 " 9 "	45,000,000
Sugar	250,000,000 " 5 "	12,500,000
Syrup and molasses .	45,000,000 gals. at 25 cts.	11,250,000
Poultry products, estimated value		200,000,000
Honey	30,000,000 lbs. at 16 cts.	4,800,000
Beeswax	1,300,000 " 25 "	325,000
Potatoes	200,000,000 bu. " 50 "	100,000,000
Butter, milk and cheese		380,000,000
Fruits		100,000,000
Rice	98,000,000 lbs. at 5 cts.	4,900,000
Vegetables		50,000,000
Tobacco	483,000,000 lbs. at 9 cts.	42,000,000
Cotton	6,500,000 bales (480 lbs.)	250,000,000
Wool	300,000,000 lbs. at 15 cts.	45,000,000
Hay	45,000,000 tons at $8	360,000,000
Miscellaneous, including flax, flax-seed, hemp, grass-seed, garden seeds, wines, nursery products, and all other enumerated agricultural products, except horses and mules		408,945,000

In this summary of total values of the agricultural productions of the country, it must not be forgotten that a portion of it is duplicated; for instance, the value of the corn that is used in feeding swine, beef cattle, milch cows, etc., will appear twice in the totals. This subject has been fully discussed by Dodge.[2]

As a general result of the detailed examination of the various forms of consumption, it is stated that fifty per cent of the maize crop is employed for feeding animals whose values are given in the summary of productions, directly or indirectly, as dairy products, poultry products, etc. Hence the total value of the agricultural products must be reduced by one-half the value of the maize, viz., $313,500,000.

For the value of hay, oats, and other crops duplicated in a similar way, an additional amount should be allowed, to swell the whole to $400,000,000. The net value of the agricultural products of the whole country may therefore be placed at $3,600,000,000.

Of the mineral constituents of the soil which have entered into

[1] See report prices for fresh meats, Quarterly Report of Bureau of Statistics, U.S Treasury, No. 3, 1885–86, p. 510. The values used are slightly less than those given in the Report.

[2] Dept. Agr., Special Report No. 57, March, 1883.

this harvest, it will be only necessary to consider two from an economic point of view, viz., potassium and phosphorus. These are not only the most important mineral plant foods, but also the most expensive and most likely to fail. With the exception of lime, they are in general the only mineral substances which the farmer buys to restore to the soil. It would be quite impossible to give the quantities of these two substances in the products above enumerated, yet some approximation to the total quantity can be made.

The mean percentage of ash in the most important of the substances mentioned is as follows:—

American wheat [1] . . .	2.06	Meats[8]	4.06
American maize[2] . . .	1.55	Eggs [9]	18.84
American oats[3]	3.18	Potatoes [10]	3.77
American barley [4] . . .	2.89	Hay [11]	7.24
American rye [5]	2.09	Cotton stalks[12]. . .	3.10
Rice [6]	0.39	Wool (washed)[13] . .	1.11
Buckwheat [7]	1.37		

To complete an approximate estimation of the mineral ingredients entering into the total agricultural products must be added the computation for the straw of wheat, etc., and the stalks of maize.

The percentages of ash in the straw of the various cereals as given by Wolff[14] are as follows:—

Wheat straw [15]	5.87	Oat straw	4.70
Rye "	4.79	Maize stalks . . .	4.87
Barley "	4.80	Buckwheat straw .	6.15

The approximate quantities of mineral matters taken from the soil by a single crop of the cereals are, therefore, as follows:—

1 Richardson, U. S. Dept. Agrl. Chem., Bull. No. 4, p. 29.
2 Ibid., Bull. No. 4, p. 67.
3 Ibid., Bull. No. 9, p. 44.
4 Ibid., p. 71.
5 Ibid., p. 57.
6 Wolff, Ash Analysis, p. 154.
7 Ibid., p. 154.
8 Wolff, *op. cit.*, p. 158.
9 Ibid., p. 158.
10 Ibid., p. 156.
11 Ibid., p. 153.
12 Ib'd., p. 156.
13 Ibid., p. 158.

14 Wolff, *op. cit.*, p. 155. Jenkins (Conn. Ex. Sta. Report, 1885, p. 19) gives the following percentages: wheat straw, 6.96; maize fodder, 4 32; oat straw, 4.72; rye straw, 1.84; buckwheat straw, 5.05.

15 For an elaborate study of the ratio of straw to grain, and the composition of the ash of each for English wheat, consult a paper by Lawes and Gilbert, Jour. Chem. Soc., Vol. XLV, pp. 305 *et seq*. Since, in general, American wheat-fields receive no manure it will be best to compare the per cents given for our wheat with those obtained from

Grain.

Name.	Wt. in lbs.	% Ash.	Wt. Ash in lbs.
Wheat	27,000,000,000	2.06	556,200,000
Maize	106,400.000,000	1.55	1,649,200,000
Oats	19,200,000,000	3.18	610,560,000
Barley	2,880,000,000	2.89	83,232,000
Rye	1,400,000,000	2.09	29,260,000
Buckwheat	650,000,000	1.37	8,905,000
Total			2,937,357,000

Straw.[1]

Name.	Wt. in lbs.	% Ash.	Wt. Ash in lbs.
Wheat	45,378,000,000	5.37	2,436,798,600
Maize	212,800,000,000	4.87	10,363,360,000

unmanured wheat at Rothamstead. For sixteen years the average was as follows (*op. cit.*, pp. 384, 385):—

Grain to 100 of straw	59.5
Weight of wheat per bushel	57.4 lbs.

The grain contained:—

Dry matter	83.33 per cent.
Nitrogen	1.90 "
Ash	2.01 "

The straw contained:—

Dry matter	83.58 per cent.
Nitrogen	.50 "
Ash	6.44 "

The ash of the grain contained:—

K_2O	32.96 per cent.
P_2O_5	49.71 "

The ash of the straw contained:—

K_2O	14.56
P_2O_5	3.79

The total weight of mineral matter removed per acre, without manure, by the wheat crop, average for sixteen years, was:—

By the grain	16.6 lbs.
By the straw	89.5 "

In plats which had received farm-yard manures only, the quantities removed were:—

By the grain	36.3 lbs.
By the straw	201.1 "

In plats having received ammonium salts only, the quantities were:—

By the grain	23.0 lbs.
By the straw	119.2 "

[1] The weight of wheat grain in the experiments of Lawes and Gilbert was a little more than half that of the straw, namely, 59.5 per cent. This was for the unmanured crop. Assuming that this ratio holds good for the American crops, the total weight of straw produced would be as given above. For the other cereals, the grain is taken at 60 to 100 of straw, except for maize, which is taken at 50 to 100.

Name.	Wt. in lbs.	% Ash.	Wt. Ash in lbs.
Oats	32,000,000,000	4.70	1,504,000,000
Barley	4,800,000,000	4.80	1,230,400,000
Rye	2,333,000,000	4.79	111,750,700
Buckwheat . . .	1,083,000,000	6.15	66,604,500
Total			14,712,913,800

The total weight of ash, in pounds, in the whole cereal production of the country, is therefore,—

In grain	2,937,357,000
In straw	14,712,913,800
Grand total	17,650,270,800

POTASH AND PHOSPHORIC ACID.

Of the ash constituents, from an economical view, we may omit all except potash and phosphoric acid. The quantities of potash and phosphoric acid removed from the soils and found in the ash of the cereals are, in each case, as follows:

Grain.

Name.	Wt. Ash in lbs.	% Potash.[1]	Wt. Potash in lbs.
Wheat . . .	556,200,000	31.16	173,311,920
Maize . . .	1,649,200,000	27.93	460,622,560
Oats	610,560,000	16.38	100,009,728
Barley . . .	83,232,000	16.33	135,917,856
Rye	29,260,000	31.47	9,208,122
Buckwheat .	8,905,000	23.07	2,054,383
Total			881,123,569

Straw.

Name.	Wt. Ash in lbs.	% Potash.	Wt. Potash in lbs.
Wheat . . .	2,436,798,600	13.65	332,623,008
Maize . . .	10,363,360,000	22.96	2,379,427,456
Oats	1,504,000,000	22.12	332,684,800
Barley . . .	230,400,000	22.85	52,646,400
Rye	111,750,700	23.15	25,870,287
Buckwheat .	66,604,500	46.86	31,210,868
Total			3,154,462,819

Total weight of potash in grain	881,123,569
Total weight of potash in straw	3,154,462,819
Grand total	4,035,586,388

[1] Wolff, *op. cit.*, pp. 154, 155.

By a similar calculation we determine the total quantity of phosphoric acid entering into the cereals of the country annually.

Grain.

Name.	Wt. Ash in lbs.	% P_2O_5.[1]	Wt. P_2O_5 in lbs.
Wheat . . .	556,200,000	46.98	261,302,760
Maize . . .	1,649,200,000	45.00	742,140,000
Oats	610.560,000	23.02	140,550,912
Barley . . .	83,232,000	32.82	27,316,742
Rye . . .	29,260,000	46.93	13,731,718
Buckwheat .	8,905,000	48.67	4,334,063
Total			1,189,376,195

Straw.

Name.	Wt. Ash in lbs.	% P_2O_5.	Wt. P_2O_5 in lbs.
Wheat . . .	2,436,798,600	4.81	117,210,012
Maize . . .	10,363,360,000	12 66	1,312,001,376
Oats	1,504,000,000	4.69	70,537,600
Barley . . .	230,400,000	4.48	10,321,920
Rye	111,750,700	6.46	7,219,095
Buckwheat .	66,604,500	11.89	7,919,275
Total			1,525.209,278
Total weight phosphoric acid in grain . . .			1,189,376,195
" " " " " straw . . .			1,525,209,278
Grand total			2,714,585,473

ACREAGE DEVOTED TO CEREALS.

In order to form some accurate opinion of the quantities of valuable plant food furnished by each acre of cereals, I refer to the following data.[2]

The estimated acreage for the several cereals is as follows:—

Wheat	40,000,000	acres.
Maize	25,000,000	"
Oats	23,000,000	"
Barley	2,500,000	"
Rye	1,800,000	"
Buckwheat	900,000	"
Total	143,200,000	acres.

The quantity of potash per acre is, therefore, for the whole cereal crop:—

4,035,586,388 ÷ 143,200,000, equal to 28.2 pounds.

[1] Wolff, *op. cit.*, pp. 154, 155.
[2] U.S. Dept., Agrl. Report of Statistician, New Series, No. 25.

The weight of phosphoric acid per acre is

$$2{,}714{,}585{,}473 \div 143{,}200{,}000, \text{ equal to } 19.0 \text{ pounds.}$$

It would be quite impossible with the data at command, as well as unnecessary, to continue this line of investigation with each of the agricultural products of the country. For the hay crop, however, a similar estimate of the quantities of plant food removed will be found of interest.

The mean percentage of ash[1] in the grasses of the United States is 7.97; for timothy[2] it is 5.88; for clover[3] it is 6.83. The mean of these three numbers will be a fair estimate for the present purpose. We will take the mean content of ash, therefore, at 6.89 per cent. Multiply now the total weight of hay produced by this number, we obtain 6,201,000,000 pounds as the total weight of ash in the hay crop of the United States.

In respect of the content of potash and phosphoric acid in the ash of hay the following data are given:—

For the ash of timothy the percentages of potash and phosphoric acid[4] are 23.80 and 8.42 respectively. For red clover, 21.96 and 6.74 respectively. The mean percentage of potash in the ash of timothy and clover is, therefore, 22.88, and of phosphoric acid, 7.56. The total weight of potash in the hay crop is therefore

$$6{,}201{,}000{,}000 \times 22.88 = 1{,}418{,}788{,}800 \text{ lbs.}$$

The total weight of phosphoric acid in the same is

$$6{,}201{,}000{,}000 \times 7.56 = 468{,}795{,}600 \text{ lbs.}$$

The number of acres harvested in the United States is about 37,500,000.

The quantity of potash removed per acre in the hay crop s therefore

$$1{,}418{,}788{,}800 \div 37{,}500{,}000 = 37.8 \text{ lbs.}$$

The quantity of phosphoric acid removed per acre is

$$468{,}795{,}600 \div 37{,}500{,}000 = 12.5 \text{ lbs.}$$

[1] U. S. Dept. Agr., Vasey and Richardson, Agricultural Grasses, p. 130.
[2] Ibid., p. 129. Jenkins (*op. cit.*) gives the following percentages:—

Clover	5.33	Mixed grasses	4.39
Timothy	3.98	High meadow hay	6.23

[3] Wolff, *op. cit.*, p. 167.
[4] Ibid.

NITROGEN.

In respect of the quantities of nitrogen removed by the cereal and hay crops the following data are given:—

The mean percentage of albuminoids in American wheats is 12.15;[1] in maize it is 10.39;[2] for oats it is 14.31;[3] in rye it is 11.32;[4] in barley it is 11.33;[5] in buckwheat it is 10.30.[6]

The total amount of albuminoids entering into the cereal crop of the country is, therefore, as follows:—

Name.	Weight.	Per cent.	Wt. in lbs.
Wheat	27,000,000,000	12.14	3,280,500,000
Maize	106,400,000,000	10.39	11,054,960,000
Oats	19,200,000,000	14.31	2,747,520,000
Barley	2,880,000,000	11.33	326,304,000
Rye	1,400,000,000	11.32	158,480,000
Buckwheat	650,000,000	10.30	66,950,000
Total			17,634,714,000

The following amounts of albuminous matter are found in the straw:—

Name.	Weight.	Per cent.	Wt. in lbs.
Wheat	45,378,000,000	3.10[7]	1,406,718,000
Maize	212,800,000,000	4.46[8]	9,490,880,000
Oats	32,000,000,000	4.00[7]	1,280,000,000
Barley	4,800,000,000	3.40[7]	163,200,000
Rye	2,333,000,000	3.00[7]	69,990,000
Buckwheat	1,188,000,000	3.90[8]	46,332,000
Total			12,457,120,000
Total in grain			17,634,714,000
Total in whole crop			30,091,183,000

[1] Richardson, Chem. Bull. No. 4, p. 30. [2] Ibid., *op. cit.*, p. 67.
[3] Ibid., Bull. No. 9, p. 42. [4] Ibid., p. 57. [5] Ibid., p. 71.
[6] Konig Nahrungsmittel, Vol. I, p. 98. [7] Armsby, Manual Cattle Feeding, p. 480.
[8] Jenkins (Conn. Exp. Sta. Report, 1879, p. 156) gives for maize fodder (green) the percentage at 1.13 and the total dry matters at 13.14. Three samples of field-cured maize fodder contained 4.46 per cent albuminoids. In the Report for 1885, 36 analyses of green maize fodder contained 18.92 per cent dry matter and 1.48 albuminoid (page 18). Six analyses of field-cured maize fodder gave 4.29 per cent albuminoid (page 19). For the calculations I have used the former number, viz., 4.46. The percentages given for some of the other straws are as follows: wheat, 4.98; oats, 3.35; rye, 4.54; buckwheat, 3.85. The use of these last numbers would increase the total nitrogenous constituents of the crop for wheat and rye, and diminish them for oats.

The quantity of nitrogen required per acre for each of the cereals is, therefore, as follows :—

Name.	No. Acres.	Wt. Alb. in Grain and Straw.	Wt. Alb. per Acre.
Wheat	40,000,000	4,687,218,000	117.2[1]
Maize	75,000,000	20,545,840,000	273.9
Oats	23,000,000	4,027,520,000	175.1
Barley	2,500,000	489,504,000	195.8
Rye	1,800,000	228,470,000	126.9
Buckwheat . .	900,000	113,232,000	125.9

The total quantity of albuminoids in the hay crop is determined by multiplying the total weight of hay produced by 7.5.[2] The total quantity is, therefore,

$$90{,}000{,}000{,}000 \times .075 = 6{,}750{,}000{,}000 \text{ lbs.}$$

This number divided by the number of acres of hay, namely, 37,500,000, is equal to 180, the number of pounds of albuminoid per acre in the hay crop.

If it be desirable to make an estimate of the total quantities of potash, phosphoric acid and nitrogenous substances, entering into the total agricultural product of the country, it may be done approximately by taking the numbers above given and the value of the agricultural products affording them, and thus making a comparison with the net value of the agricultural products of the country.

It would, of course, be preferable, as has been intimated before, to calculate the quantities of plant food for each item separately,

[1] This may seem a small quantity, but it must be remembered that it is based on the average yield of American wheat-fields, which is only 12–13 bushels per acre. Lawes and Gilbert (Address of Professor Gilbert before A. A. A. S., Montreal, 1882) have found the yield of albuminous matter for the wheat crop at Rothamstead for thirty-two years to be 129.4 pounds per acre. The yield of wheat, however, averaged 14 bushels per acre (Jour. Roy. Agr. Soc., No. 11, Oct., 1884, p. 126). For an average yield of 12 bushels per acre the nitrogenous matters would have amounted to 110 pounds per acre.

[2] Jenkins (Conn. Exp. Sta. Report, 1885, pp. 18 and 19) gives the average percentages of protein matter in hay, as follows :—

Clover hay	11.44
Timothy hay	6.02
Mixed hay	6.76

Since the hay crop of the country is a mixture of a large number of grasses with a considerable amount of clover, I have taken the mean of 7.5 per cent as a fair measure of the nitrogenous matters in the hay crop.

but the data for such calculations are not all at hand. For instance, in the case of cotton, while the yield of fibre and seed is approximately well known, the percentage of stalks and their exact composition are not.[1]

The same is true of sugar-cane and for the grass crops devoted to grazing, etc. It is not essential, however, to the purpose of this address to give all these matters in full detail. The value of the cereals which have been the subject of the above calculations is $1,282,880,000; the value of the hay is $360,000,000; total value, $1,642,880,000.

Compare this with the total net value of the agricultural products, viz., $3,600,000, and we find that it is 45.6 per cent of the whole.

For the present purpose it may be assumed, therefore, that the potash, phosphoric acid, and albuminoids removed in the crops mentioned are 45.6 per cent of the whole quantity entering into the entire agricultural product. The entire quantity of potash, phosphoric acid and albuminoids, therefore, entering into the agricultural harvest of the United States for one year is :—

Total potash	= 5,454,375,188 × 100 ÷ 45.6 =	11,961,348,923 lbs.
Total phosphoric acid	= 3,183,381,075 × 100 ÷ 45.6 =	6,981,098,848 "
Total protein	= 36,841,834,000 × 100 ÷ 45.6 =	80,793,495,614 "

[1] According to Dabney (Proceedings 306th Meeting Soc. Arts, Mass. Inst. Technology, "The Chemistry of Cotton"), one bale of cotton fibre contains,

Phosphoric acid	.60 lbs.
Potash	2.10 "

The yield of cotton-seed is double the weight of fibre; hence, for the whole country it is 6,240,000 pounds. Of this weight half is kernel and the other half hull. The kernels contain 4.03 per cent ash, or in all 125,736,000 pounds. The composition of the ash is as follows:

Phosphoric acid	42.93 per cent.
Potash	28.37 " "

The weight of potash in the ash of the kernel is therefore, 35,671,303 pounds, and of phosphoric acid 43,978,464 pounds.

The cotton-seed hulls amount to 3,120,000,000 pounds, and contain 2.28 per cent ash, equal to 71,136,000 pounds. This ash contains:

Phosphoric acid	4.07 per cent.
Potash	57.95 " "

The total weight of potash in the ash of the hulls is, therefore:

	Potash	41,223,312 lbs.
and of	Phosphoric acid	2,895,235 "

Taking this last number, we determine the total amount of nitrogen entering into the agricultural harvest for one year by dividing it by 6.25, or in all 12,926,929,302 pounds. The value of the potash, phosphoric acid, and albuminoids, or nitrogen, entering into a single harvest, is obtained from the following estimates, viz.:—

Potash	5 cts. per lb.
Phosphoric acid	6 " "
Nitrogen	18 " "

The total value of each of these ingredients is therefore:—

Potash	$ 598,067,446
Phosphoric acid	418,865,930
Nitrogen	2,326,852,674
Total	$3,343,786,050

These quantities of plant food removed from the soil annually seem enormous, but it must be remembered that they are not all lost; much of them is left in the soil, in roots, straw, stalks, etc. Those, however, who are acquainted with the method of farming practised in the newer parts of our country know that corn-stalks and straw are generally regarded as nuisances, to be removed as easily and speedily as possible. It is not tilling the soil, but killing it, that is practised. Stables are removed to get out of the way of the accumulating manure, and the corn-stalks are raked together and burned to prepare the field for a new crop. True, in many localities the waste of such a proceeding, especially in nitrogen, is understood. Yet it must be confessed that over vast areas of our agricultural lands there is no conception of the idea of possible exhaustion of the soil, and no systematic method of preventing it. The refuse of the crop, the straw, the stalks, etc., are put out of the way as easily and quickly as possible, and without thinking of the robbery which is thereby committed.

The stores of plant food which have accumulated in our virgin soils are indeed great, but they cannot withstand this constant drain on them. The effects of this system of culture soon show themselves in diminished yield, as is seen in the great wheat-fields of the Northwest and of California, which do not produce at the present time more than half the crop at first obtained from them.

If we place the annual contribution of potash of an acre of land to the crop at 40 lbs., the number of crops which could be produced in a given depth as far as this constituent of soil is concerned is easily computed. The weight of dry soil per acre to a depth of nine inches is approximately 3,000,000 pounds.[1] A soil containing .3 per cent of potash would have, therefore, 9,000 pounds, which at 40 pounds a year would last for 250 years. But fortunately, by the decomposition of feldspathic rocks and others containing potash, and also by the transfer in various ways of the potash of the sub-soil to the soil, a provision is found which will prevent the entire exhaustion of the soil. Thus it happens that in many parts of the world where fields have been under cultivation for hundreds of years there is still a sufficient amount of this manurial substance to insure the production of a crop.

Further, it must not be forgotten that there are many manurial substances containing potash which are accessible, and which will furnish immense stores of this substance to the future agriculturist. Chief among these natural deposits must be mentioned the mines of kainite, which have their greatest development near Stassfurt. These mines have already furnished immense quantities of potash, and there is no immediate danger of their exhaustion. The quantity of kainite entering into consumption in the United States for the fiscal year ending June 10, 1884,[2] was 126,166 tons, valued at $757,014. For the year ending June 30, 1885, the quantity was 84,219 tons and the value $483,780. The quantities of chloride of potash imported during the same periods were 48,712,767 pounds and 40,839,704 pounds, valued at $731,409 and $613,674 respectively. Although the greater part of the last-mentioned compound is used in chemicals and the arts, yet it may be considered as finally reaching the soil, either directly or indirectly. In round numbers, the value of the potash salts imported may be placed at a million and a half of dollars. Kainite appears to be peculiarly useful to cotton, since, according to Dabney,[3] it prevents "rust" and thus adds largely to the yield.

The available quantity of phosphorus as plant food may be

[1] Richards, Dept. Agrl. Chem., Bull. No. 10. p. 28.

[2] Commerce and Navigation of the U. S. Bureau of Statistics, U. S. Treasury Department, 1885, pp. 575–577.

[3] Proceedings 30th Meeting Soc. of Arts, Mass. Inst. of Tech., "The Chemistry of Cotton."

estimated in the same way. The quantity of phosphoric acid in soils varies from none at all to almost one per cent.[1]

If we take the mean content of phosphoric acid in a soil to be .15 per cent, the total quantity per acre to a depth of 9 inches would be 4,500 pounds. If the contribution to each crop is 20 pounds per acre, the phosphoric acid would last for 225 years without any artificial supply.

The stores of phosphoric acid, however, which a provident past has saved for us, are even greater than the deposits of potash. Apatite is a somewhat abundant mineral, and in South Carolina and Alabama, and other states of the Union, are found large beds of phosphates. Some idea may be formed of the extent of these deposits by studying the dimensions of the largest bed of them yet discovered, having its centre at Charleston, S. C. This bed[2] has been traced for a distance of seventy miles parallel with the coast, and has a maximum width of thirty miles.

For the year ending May 31, 1884, the yield of crude phosphates in South Carolina alone was 431,779 tons, and during the next year, 395,408 tons. The average price per ton has been about $5.50. Attention was first called to the phosphate resources of North Carolina by C. W. Dabney, jr.,[3] and to the Alabama deposits by Prof. W. C. Stubbs.[4]

In view of the fact that only preliminary surveys have been made of these phosphatic beds in North Carolina, Alabama, and Florida, and that these surveys have shown the presence of immense quantities of these deposits, it is just to conclude that the mineral wealth of the country, in this particular, is of no mean proportions.

The beds of apatite which were formerly operated in our New England states have ceased to be profitable since the discovery of the southern phosphate rocks, but the Canadian apatite is still mined, and the product rapidly increasing. In 1884 the output amounted to 22,143 tons of 2,200 pounds, and the market value was about $30 per ton, or $664,290. Very little of this product, however, reaches the United States, being sent mostly to Great Britain.

[1] U. S Dept. Agrl. Chem., Bull. No. 10, pp. 54–56.
[2] Williams, Mineral Resources, U. S. Geol. Survey, 1883–84, p. 783.
[3] Report N. C. Agrl. Exp. Sta., 1883, pp. 56 *et seq.*
[4] Williams, *op. cit.*, pp. 794 *et seq.*

The quantity of phosphates imported into the United States (not including guano[1]) has diminished with the increase of home production, having fallen from 133,955 tons, worth $1,437,442, in 1883, to 27,506 tons, worth $367, 333, in 1885.

Of late years the fertilizing value of bones has received a practical recognition, and they are carefully saved to be ground into bone meal or worked into acid phosphate. The plains of the west have also been cleared of the accumulated bones of former buffaloes, a source which unhappily, by the rapid extinction of the herds, will soon fail.

According to Lawes and Gilbert,[2] the mean percentage of bone in swine is 7.0. In 5,600,000,000 pounds the total weight of bone would be 392,000,000 pounds. In beef cattle the mean percentage of bone is 11. For 4,000,000,000 pounds the total weight of bone would be 440,000,000 pounds. In mutton the percentage of bone is 7.8, and for 500,000,000 pounds would give 39,000,000 pounds. Add to these sums the weight of bones obtained from dead horses, mules, etc., which may be estimated to be about 25,000,000 pounds, and we get the following results :—

Bones from beef cattle	440,000,000
" " pork	392,000,000
" " mutton	39,000,000
" " horses, etc.	25,000,000
Total	896,000,000 lbs.
	or 448,000 tons.

This immense quantity of bone is not valuable alone for the phosphoric acid it contains, but also for its combined nitrogen. It is worth fully $30 per ton, amounting in all to $13,440,000.[3]

[1]The quantity of guano imported in 1884 was 32,684 tons, valued at $627,872. (De Ghequier, The Fertilizer Movement for 1883–84, p. 41.) The total quantity of commercial fertilizers used in the United States during that year is estimated at 966,000 tons (p. 34). At $30 per ton this would amount to $28,980,000. The amount of money paid by the farmers of the country at the present time for commercial fertilizers is more than thirty million dollars, and is rapidly increasing,

[2]Jour. Roy. Agrl. Soc., Vol. XXI, pp. 433 *et seq.* In two animals examined by McMurtrie (Report Illinois Indust. Univ., 1884, p. 159), the percentage of bone was as follows; Poland China pig, 11 months old, gross weight 346 lbs., 6.30; Berkshire pig, 9 months old, gross weight 245 lbs., 6.73,

[3]Lawes and Gilbert (Proceed. Roy. Soc., Vol. XXV, p. 344) make the following comments on the contributions of the soil to fat animals; "The loss to the farm

Sentiment and abundance have heretofore protected the bones of man from economic use, but future necessity for nourishment and the gradual loss of phosphorus in the soil may yet cause an invasion of the catacombs and crowded cemeteries. In passing the cords of cross-bones and pyramids of grinning skulls in the catacombs, one cannot help thinking how much better they would look incorporated in fields of waving wheat, and cribs of yellow corn.

LOSS OF PLANT FOOD BY EXPORTATION.

For the fiscal year ending June 30, 1885, farm products were exported from the United States having a value of $530,172,835. The value of agricultural products imported was $249,211,975, more than half of which were sugar, tea and coffee. The excess of exports over imports was, therefore, $280,960,860.

It must be remembered, however, that the values of exports are given at the seaboard, and are fully 25 per cent greater than for the values given for the farm. To compare, therefore, exports with total production, the sum above given must be diminished by one-fourth, becoming $397,629,626, or 11 per cent of the total net value of the farm production of the country.

Allowing for the small quantities of valuable plant food introduced in our agricultural imports, we may safely place the loss of these ingredients due to exportation at 10 per cent of the whole. The figures become, therefore, for

Potash	119,613,489 lbs.,	worth	$5,980,674
Phosphoric acid	69,810,988 "	"	4,188,659
Nitrogen	129,269,593 "	"	23,268,527
Total value exported			$33,437,860

of mineral constituents by the production and sale of mere fattening increase was very small. It was greater, of course, in the case of growing than of only fattening animals. In illustration, the amounts of some of the more important mineral constituents removed annually from an acre of fair average pasture and arable land were compared. Such estimates could obviously be only approximate, and the quantities will vary considerably. With this reservation, it may be stated that of phosphoric acid an acre would lose more in milk, and four or five times as much in wheat or barley grain or in hay, as in the fattening increase of oxen or sheep. Of lime, the land would lose twice as much in the animal increase as in milk, or in wheat or barley grain; but perhaps no more than one-tenth as much as in hay. Of potash, an acre would yield only a fraction of a pound in animal increase, six or eight times as much in wheat or barley grain, and more than one hundred times as much in hay."

The exportation of agricultural products becomes, therefore, a slow but certain method of securing soil exhaustion, and this accounts for the fact that countries, or those portions of countries, which are devoted to almost exclusive agricultural pursuits, thus causing a continuous exportation of agricultural products, become the homes, not of the richest, but of the poorest communities.

It would be useless to deny, in this connection, that our own country, with a soil enriched by centuries of accumulating nitrogen, has grown rich from its agricultural exports. But when the last of our virgin soil shall have been placed under cultivation, a continuous stream of such exports will certainly impoverish the nation, and reduce all who practise such agriculture to the condition which has already been reached by those who have for years grown tobacco, corn, cotton and wheat on the same soil, and sold the products without paying back to the field the percentage of profits which was its due.

On the other hand, the farmer who is fortunate enough to be permitted to patronize the home market, who sells his maize and takes home a load of manure, adds not only to the plethora of his purse, but also to the fertility of his soil.

Thus in the light of agricultural chemistry, we see clearly the deep scientific basis of the teachings of political economy which show the value of the home market. While, therefore, the statement made at the commencement of this address, that the chief factor in the prosperity of a country is its agriculture, remains in every sense true, yet from the data discussed it as readily appears that agricultural prosperity is most intimately connected with the advancement of every other industry. Agricultural chemistry teaches the farmer to welcome the furnace and the mill, for in their proximity he secures a sure return to his fields of the plant foods removed in his crops.

We have seen by the foregoing discussion, that, without any artificial additions, the soil, excluding the subsoil, contains enough of the two most important and valuable mineral constituents of plants to produce an average crop annually for two hundred and fifty years. In point of fact, however, the impoverishment of the soil takes place at a much slower rate than this theory would indicate. It would, indeed, be a sorry thought to consider that in a quarter of a millennium the agricultural area of the earth would be incapable of producing further yields. Doubtless much

of this reserve food is brought from the subsoil, and if it be possible for the subterraneous stores of these materials gradually to work their way surfacewards, even the remote future need not fear a dearth of them.

There is also a certain conservatism in crops, a vegetable "good breeding," which prevents the growing plant from taking all the food in sight. As long as there is abundance, the plant is a hearty eater; but when the visible quantity of food falls to a certain minimum, it remains for a long time without any rapid diminution. This fact is well illustrated in the experiments of Lawes and Gilbert at Rothamstead, where wheat was grown on the same unmanured field for forty years in succession.[1]

In the "Summary and General Conclusions" derived from these experiments, these celebrated agronomists say:[2] "A soil, which in the ordinary course of agriculture would have received an application of manure before another crop was sown, has produced crops of wheat in succession, averaging fourteen bushels per acre, solely by means of its existing fertility. . . . The stock of potash and phosphoric acid has been largely reduced. Although so much soil fertility has been removed, the stock that remains would appear to be sufficient to grow crops of wheat for a very long period; the produce, however, must, in process of time, necessarily be lower than it has hitherto been."

NITROGENOUS FOOD OF PLANTS.

If we pass now to discuss the value, the source, and the probable supplies of the nitrogen used as plant food, we meet at once a more difficult problem. It has already been shown that the weight of nitrogen entering into the agricultural product of the United States for a year is nearly thirteen billion pounds, of a cash value in round numbers of two and a quarter billion dollars.

In view of the fact that nitrogen is one of the most abundant of the elements, it may appear somewhat strange that there should be so high a value placed on it, or that there should be any question of the abundance of the supply.

[1] Boussingault states that on the high plains of the Andes he has seen grainfields, which had produced good harvests for two hundred years in succession. (Mayer Agriculturchemie, 3, Auflage, p. 369.)

[2] Jour. Roy. Agrl. Soc., No. XI, Oct., 1884, pp. 446, 447.

The weight of nitrogen resting on each square meter of surface is a little more than 8,000 kilograms, which, at 40 cents a kilogram, would be worth $3,200. At the bottom of this vast ocean of plant food, it seems hard to compel the needy farmer to pay so high a price for it. The question, therefore, "Whence comes the nitrogen assimilated by the plant?" is of as much interest from an economic as from a scientific point of view. It is thus evident that, from an economic view, the problem of the supply of nitrogen for future crops is entirely different from that of potash and phosphoric acid. In the latter cases, we have a definite amount of material, and this can be made to do duty over and over again. It is a question simply of economy, and a wise use of the great stores which Nature has provided, and a careful restoration to the soil of the quantities removed by successive crops.

In respect of nitrogen, however, the case is far different. Combined nitrogen, as albuminoids, tends to rapid decay, and hence we must look to the minute and mysterious operations of nature to preserve the equilibrium between free and available nitrogen on which every form of life depends.

In respect of the forms in which nitrogen enters into plant life, there has been much discussion, and there remains much difference of opinion. The possible sources of it are as follows:—

1. Organic nitrogenous matter.
2. The ammonia that may exist in the air, or be derived from the waters of the ocean.[1]
3. The nitrous and nitric compounds formed by combustion.
4. The same, formed by electric discharges, or by differences of electric potential.[2]
5. Nitrogen fixed in the soil by microbes.
6. The free nitrogen of the atmosphere.
7. Mineral nitrates.

1. *Organic Nitrogen.*

Without entering here upon a critical study of the views held by scientists in respect of the assimilation of nitrogen, I will content myself with trying to give very briefly the results which have been obtained by recent investigations.

[1] The water of the ocean contains 13.8 parts per million. (Mayer, *op. cit.*, p. 91, foot note.)

[2] The supplies 3, 4, and perhaps some of 2, are brought chiefly by the rain.

It has long been acknowledged that organic nitrogen, *i. e.*, nitrogen in the form of protein or albuminoid matter, is one of the chief sources of similar compounds in the growing plant. For many years it was supposed that the simple decomposition of such matter yielded its nitrogen in a suitable form for assimilation. It is now, however, an established fact, that nitrogen before it can be absorbed by the growing plant must be oxidized,—in other words, converted into nitric acid. The first great advance in our knowledge of this interesting process has doubtless come from the discovery of the method by which organic nitrogen is prepared for plant food.

Nitrification.

It would not be proper to take time here to enter into a detailed discussion of the process by which organic nitrogen, or nitrogen of any kind, is converted into nitric compounds, a process which is of the utmost importance to vegetable growth, and which it is now generally conceded is due to a kind of fermentation set up by a special organism. Thanks to the results of the patient and fruitful investigations of Pasteur, it has been possible to secure pure cultivations of this nitric ferment. Perhaps the chief credit of this achievement is due to Schlösing and Müntz,[1] but the part taken in it by Warrington, Berthelot, Dehérain, and Joulie must not be forgotten.

Schlösing and Müntz[1] give the results of their experiments with this ferment. The authors say :—

"We have shown that natural nitrification is to be considered as the result of a phenomenon analogous to fermentation, but that the oxidation of the nitrogen is not produced in a general manner, by the organisms which are the usual agents of the combustion of organic matter, and that it appears that it must be attributed to a special organism.

"In examining with a microscope, of a very large magnifying power, nitrifiable vegetable mould, or earth containing vegetable matter, there are seen, near the organic débris, organisms of the most varied kind. Even where nitrification is the most active, however, it is difficult to determine the more special organism to which it ought to be attributed."

The authors next describe the results of their cultures in sterilized

[1] Comptes Rendus, Vol. LXXXIV, pp. 301 *et seq.*, and Vol. LXXXIX, pp. 891 *et seq.*, and 1074 *et seq.*

sewage waters, by means of which they obtain the pure cultivation of the nitric ferment, "a punctiform corpuscle of very small dimensions, presenting a great analogy in form to the organisms which Pasteur has found in waters, and to which he has given the name of 'brilliant corpuscles' and which he regards as the germ of bacteria."

"It multiplies in appropriate liquids, but slowly, causing the nitrification to be less active at the beginning of a seeding and afterwards to increase progressively.

"It seems to multiply by budding; and it is frequently seen under the form of globules, coupled together, thus affording some analogy to the acetic ferment.

"The nitric ferment is not endowed with the resistance which is found in some of its congeners. A temperature of 100° retained for ten minutes invariably kills it; even a lower temperature, namely, 90°, is sufficient to arrest its action.

"Desiccation, even at an ordinary temperature, acts unfavorably to it. Some soil, from a locality of energetic nitrification, became completely sterile after having been dried by exposure to the air, and this sterility was maintained even when the most favorable conditions of nitrification were applied.

"The nitric ferment is of wide distribution; vegetable mould is the place most favorable to it: it is also there that it performs its most valuable functions. It is rare to find a particle of arable earth unsuitable to its growth.

"Sewage waters, in general, and waters containing organic matters, are rich in nitric ferment, and we have shown that in the presence of these liquids it is capable of performing its functions, and thus tends to their purification.

"Below 5° the formation of nitrates is extremely restricted, if not altogether null; at 12° it becomes appreciable, at 37° it attains its maximum activity; above 35° there is no longer any trace of nitrification. The access of oxygen is an essential condition."

The authors also show that a feeble alkalinity is necessary to the formation of nitrates. In nature it is the carbonate of lime which furnishes the alkalinity. The presence of organic matter is also necessary; sugar, glycerine, alcohol, tartaric acid, etc., can furnish the carbon indispensable to this reaction as well as the organic matters in the soil. The authors also point out that nitrates are not always the result of this oxidation, but sometimes nitrites,

which as will be seen hereafter, Warrington ascribes to a special kind of ferment. The production of nitrites is more frequent in liquids than in soils, and is observed usually at a temperature of 20° or below. The researches of Schlösing and Müntz, of which a brief abstract has just been given, stimulated others who were working in the same line to continue and amplify the work which had been so well commenced.

Warrington[1] has given a most valuable *résumé* of the experiment on nitrification conducted at the Rothamstead laboratory, the first part of which was published in a previous number of the "Transactions of the Chemical Society."[2]

He shows that the opinion of Dr. Angus Smith, that nitrification may take place by a simple oxidation of albuminous matter is erroneous; and gives additional testimony that such a process is due to an organism. He, however, modifies the statement in his first paper, that this nitrifying organism is not a bacterium.

Warrington's paper has one great advantage over most of those which bear on this subject, in that it contains a minute description of the method and mechanism of the experiments. By reason of this detailed description, we are able to form a much truer notion of the value of his results. He shows that the nitrifying organism is most abundant and most active near the surface of the soil. In sterilized solutions seeded with soil taken above the depth of nine inches, there was no failure in any case to produce nitrification. Below nine inches, the results were irregular. Only in two instances was nitrification produced with soil taken at the depth of eighteen inches, and in one case only at a greater depth, and in this case the activity of the soil was probably due to some accidental contamination.

Warrington experimented with various forms of albuminoid matter, viz., milk, asparagine, rape-seed, etc., and in all cases succeeded in completely nitrifying them, while in duplicates kept free of the ferment no nitrification was produced.

The necessity of a salifiable base to complete nitrification was also made apparent by the results obtained. Thus, as was shown by Schlösing and Müntz, a certain degree of alkalinity is necessary to complete a rapid nitrification.

In a later communication,[3] Warrington has shown that ammo-

[1] Jour. Chem. Soc., Vol. XLV, p. 637, *et seq.*
[2] 1879, p. 429, *et seq.* [3] *Op. cit.*, 1885, p. 758, *et seq.*

nium carbonate solution containing four hundred parts of nitrogen, and over, to one million, suspends the action of the nitrifying ferment. This, however, begins again on the addition of gypsum. The favorable action of the gypsum is due to the double decomposition with the ammonium carbonate, and not, as Pichard[1] supposes, to its carrying a supply of oxygen.

A heavy application of caustic lime also suspends or retards nitrification in the soil. When, however, the lime unites with carbonic acid, its presence then becomes favorable to the process.

Warrington is, moreover, of the opinion, that the nitric and nitrous ferments are different in their nature, and that the former is more sensitive to a low temperature than the latter, a fact which agrees with the observation in respect of the formation of nitrites made by Schlösing and Müntz.

A process directly the reverse of nitrification has also been observed by Gayon and Dupetit,[2] by which nitrates are destroyed by a denitrifying ferment. This ferment is described as an anaerobe. It acts most vigorously at a temperature of from 35° to 40°, and the experimenters, under favorable conditions, succeeded in totally decomposing a five per cent solution of nitrate of potassium. Heat, chloroform or sulphate of copper sterilized the solutions, but carbolic and salicylic acids do not interfere with the fermentation; on the contrary, are themselves decomposed, like organic matters. The gas evolved is pure nitrogen, representing a large portion of the nitrogen originally present in the nitrate. The rest of it forms ammoniacal compounds.[3]

[1] Ann. Agronomiques, 1884, pp. 310, 311. "La supériorité du sulfate de chaux comme agent nitrificateur, magré son insolubilité relative, eu égard aux sulfates de potasse et de soude, tient, sans doute, à sa facilité d'être désoxydé au contact des matières organiques et réoxydé au contact de l'air."

[2] Comptes Rendus, Vol. XCV, p. 644 *et seq.*

[3] Gayon and Dupetit report the latest results of their investigations of the denitrifying ferment in the "Journal de Pharmacie et de Chimie." July, 1886, pp. 34, 35.

They claim to have isolated two bacteria (*Bacterium denitrificans* α and β). These two microbes multiply with equal facility in meat broth and in an artificial liquid containing ten grams nitrate of potash in 1,000 cc., together with appropriate quantities of organic matter and phosphates. Whether the nitrogen is set free pure, or mixed with some nitrous oxide, is determined by the character of the nutritive liquid. If the organic matter is nitrogenous, ammonia is formed, and also some free nitrogen. The decomposition of nitrates by *B. denitrificans* does not appear to be a true fermentation; it is a combustion of organic matter by the oxygen of the nitrate, attended with the disengagement of a large quantity of heat.

In respect of the decomposition of nitrates in the soil, Schlösing[1] has shown that in sealed vessels certain soils emit a gas composed of carbonic dioxide and nitrogen.

Dehérain and Maquenne[2] confirm the observation of Schlösing, and seek further to discover the origin of the free nitrogen. A soil rich in organic matter gives rise to free nitrogen, while one poor in it does not. In addition to free nitrogen, nitrous oxide was also detected. The authors also confirm the observations of Gayon and Dupetit above cited, that heat and chloroform sterilize an earth containing nitrates, and prevent the action of the denitrifying ferment. When, however, a soil thus sterilized by heat is reseeded with a portion of denitrifying earth, it regains its original power. In further experiments, they show that the active cause of the phenomenon of dentrification is probably the butyric ferment described by Von Tiegham under the name of *Bacillus amylobcater*.

2. *Ammonia.*

The existence of ammonia in the air is a well-established fact; and even without the aid of rain it is possible that some of this substance may be absorbed by the soil and undergo nitrification. It is equally true that the soil also gives up ammonia sometimes to the air, and thus it is hard to determine whether, upon the whole, there is much gain from this source. The settlement of the question depends largely on the methods of determining the ammonia in the soil, a subject over which there is just now an animated discussion between Schlösing and Berthelot.[3]

In the opinion of Berthelot, a moist arable soil tends constantly to emit ammonia into the atmosphere, derived chiefly from the dissociation of ammonium carbonate.[4] On the other hand, the opinion of Schlösing is entirely different, asserting that in general a soil containing vegetable matter, wet or dry, tends to take ammonia

[1] Comptes Rendus, Vol. LXXVII, pp. 203 and 353.

[2] Ibid., Vol. XCV, pp. 691, 732, 854.

[3] Ibid., 1886, Vol. CII, Nos. 17, 18, 20, 22, 23, 24, and 25.

[4] Ibid., 1886, p. 953: "Il en résulte que, dans tout sol qui renferme du carbonate de chaux, les sels ammoniacaux tendent à changer en carbonate d'ammoniaque, or, ce dernier sel étant décomposé partiellement dans ses dissolutions il en résulte une mise en liberté continue de l'ammoniaque."

from the air. A dry earth continues the absorption until the tension of the ammonia therein is equal to that in the atmosphere. A moist earth absorbs even more, since the ammonia in it is converted into nitrates as fast as it is absorbed, and thus its tension in the soil is kept much below that in the air.[1]

The whole question of the absorption of ammonia by the soil may, therefore, be regarded as unsettled.[2] Schlösing has established beyond doubt the increase of ammonia in dry soils during August and September; but, as Berthelot justly remarks,[3] he has not shown that this increase comes from the air rather than from the decomposition of nitrogenous matters in the soil, going on in the usual way, and doubtless a step in the process of nitrification; the increase being due to the fact that the growing crops, approaching maturity, were using less of the available nitrogen than before. In any case, it is now quite impossible to form any just estimate of the value to the crop of the ammonia absorbed by the soil from the air.

3. *The Oxidation of Nitrogen due to Combustion.*

It is well known that in certain forms of combustion there is an oxidation of free nitrogen to nitrous or nitric combinations. Years ago De Saussure detected ammonia, nitrous and nitric acids formed in water from the explosion of hydrogen and oxygen, and Schlösing detected such compounds in the products of burning fats, oils, wood, etc. But in these cases, granting the accuracy of the experimental methods, the quantities of nitrogen entering into combination are extremely minute, and can have no economic interest. This oxidation of nitrogen is especially noticed in the combustion of metals, although it cannot be doubted that the presence of ozone has sometimes been mistaken for nitrous compounds. The preëxisting mineral nitrogen, to which reference will soon be made, may have had its origin in the early history of our planet, if we accept the

[1] Comptes Rendus, Vol. CII, p. 1002. For the content of ammonia in the air, see Mayer, *op. cit.*, p. 195.

[2] The carbonate of ammonia, it is claimed, may be produced in large quantities synthetically by passing pure moist nitrogen over a mixture of barium oxide and charcoal heated to 300°. The water is decomposed, the hydrogen uniting with the nitrogen and the oxygen forming carbonic dioxide with the carbon. (Bolton, Progress of Chemistry, 1885. Smithsonian Report 633, page 13.)

[3] Comptes Rendus, Vol. CII, p. 1090.

theory that at one time the temperature of our earth was so high that even metals existed in a state which we now call dissociation. As the temperature of the terrestrial gases fell, there was a combination of the metals with oxygen, and this was attended with the formation of a vast quantity of nitrous and nitric nitrogen. Kämmerer[1] pointed out that, by burning hydrogen, small quantities, and by burning magnesium large quantities of nitrogen were oxidized.

Müntz and Aubin[2] found that in the combustion of one gram of hydrogen there was formed one milligram of nitric acid, while the burning of one gram of magnesium gave one hundred milligrams of it. These authors, therefore, suppose that at the first advent of vegetable life there were present on the earth immense quantities of nitrates, and that the exuberance of vegetation during the geologic epochs was due largely to this cause. On the other hand, it is evident that in ordinary combustions the nitrogen set free is far in excess of the quantity oxidized, so that the process of combustion can no longer be regarded as a source of supply of combined nitrogen.

4. *Nitrogen oxidized by Electrical Discharges.*[3]

The quantity of nitric nitrogen produced by electrical discharges is difficult to determine. It varies with the climate and season, and is probably greater in tropical than in temperate regions. It is generally supposed to be due to electric discharges known as lightning, although Berthelot has pointed out the fact that nitrogen may be fixed in organic matter by the influence of difference in electrical potential.[4] In respect of the total nitrogen oxidized by electrical discharges, a fair estimate may be made by determining the quantity of such nitrogen reaching the surface of the earth in rain-water. The presence of ammonia in the air was first noticed by De Saussure,[5] and its combination with nitric acid in the air was first pointed out by Liebig.[6] The determinations of the quantity of ammonia and nitric acid in rain-water by different chemists and in

[1] Ber. d. deutsch. Gesellsch., 1877, pp. 16 and 84.
[2] Comptes Rendus, Vol. XCVII, p. 242.
[3] Cavendish (Kopp, Geschichte der Chem., Vol. III, p. 277) was the first to show the conversion of nitrogen into nitric acid by the electrical discharge.
[4] Comptes Rendus, 1876, p. 677.
[5] Recherches sur la Végétation, p. 207.
[6] Chem. in ihrer Anwend., Vol. I, p. 317.

various localities have been tabulated by Mayer.[1] Naturally, the percentage of these substances would depend largely on the amount of rainfall, and hence a better method of estimating it would be by giving the weight of combined nitrogen precipitated on each acre or hectare.

Harrison, in a tropical region,[2] has found in ammonia and nitrates .225 parts of nitrogen per million in the rainfall for eight months.[3] The amount of rainfall during the time of the experiments was 33.65 in., from which it does not appear that the contribution of combined nitrogen from the air is greater in tropical than in temperate regions.[4]

From a comparison of the various determinations accessible, it appears that the mean weight of combined nitrogen received from the air in the rain-waters is about 12 kg. per hectare, or ten pounds per acre. In any case, the quantity of combined nitrogen received from the air is many times less than that removed by the growing crop. It appears, from the continued ability of the soil to furnish a sensibly constant quantity of combined nitrogen to crops during long periods of time, that the amount received in this way from the air is an even compensation for what is lost in the free nitrogen arising from combustion, decomposition, and the denitrifying ferment already mentioned, provided neither the air nor the plant has the property of fixing free atmospheric nitrogen.

5. *Fixation of Nitrogen in Soils, and*, 6. *Fixation of free Nitrogen by the Plant.*

Dehérain[5] discusses the question of gain and loss of nitrogen in soils. He shows, from his own experiments and from those of Lawes, Gilbert and Warrington, that a soil constantly cultivated will lose nitrogen, no matter how much of it is added in the form of soluble fertilizers, while an uncultivated field will gain in nitrogenous material.

[1] Agriculturchem., 3 Aufl., pp. 191, 195.

[2] Barbadoes Agricultural Gazette, June, 1886, p. 11.

[3] June to February inclusive.

[4] In addition to the nitrogen brought to the soil by rain in the form of ammonia and nitric acid, a considerable quantity is furnished in the dust and corpuscles removed by the rainfall from the air. (Comptes Rendus, Vol. CII, p. 957.)

[5] Ann. Agronomiques, XII, No. 1, p. 17 *et seq.*, and No. 3, p. 97 *et seq.*

In a series of interesting experiments, Berthelot[1] has shown that soils have the power of fixing the free nitrogen of the air, by the action of an organism, without nitrification.

He says, in summarizing the results of the studies:—

"The argillaceous soils, sands, and kaolins possess the property of slowly fixing the free atmospheric nitrogen. This property is independent of nitrification, as well as of the condensation of ammonia. It is due to the action of certain living organisms. It is not manifest in winter, but it is especially exerted during the season of vegetable activity. A temperature of 100° destroys it. It is exercised as well in closed vessels as in contact with the atmosphere; as well in air completely free, at the top of a tower, as under a roof; in the neighborhood of soil covered with vegetation, as in a closed chamber. It takes place in the dark, but less actively than in the light."

NATURE OF THE ORGANISMS WHICH FIX THE FREE NITROGEN OF THE AIR IN THE SOILS.

Berthelot says: "The researches which I have made on the direct fixation of free nitrogen in different classes of soils, a fixation which is carried on by certain organisms, have led me to seek some other appropriate way of indicating the quantity of these. It does not appear possible to isolate these organisms, which seem to belong to a group of diatoms; but we are able to form an idea of their abundance by estimating the carbon which enters into the composition of their tissues."[2] Berthelot continues his paper by discussing the best methods of estimating this carbon, for the details of which I refer to the original paper.

As a result of the determinations made, it was found that one kilogram of nitrogen-fixing soil towards the end of the experiment contained from one to two grams of organic matter, due to the diatoms present.

For a thickness of soil such as was used in the experiments, Berthelot calculated that the fixation of nitrogen per hectare amounted to from 16 to 32 kilograms for the extremes, or a mean of about 25 kilograms per hectare. But when allowance is made for the additional thickness of soil, the quantity becomes very much greater.

[1] Bull. Soc. Chem., Vol. XIV, No. 3, pp. 121 *et seq.*
[2] Comptes Rendus, Vol. CII, No. 17, 1886.

Whence it appears that the free nitrogen fixed by these non-nitrifying organisms is much greater in amount than that brought to the soil by the rains,—an amount estimated by Lawes and Gilbert at 8 kg. per hectare. Boussingault[1] estimated the mean weight of combined nitrogen received by the rains at 2.7 kg. per hectare, while Barral placed it at 19.64 kg. The mean weight found by the Russian experiment stations was 11.5 kg.

In any case, therefore, it is seen that the quantity of free nitrogen fixed by the soil is greater than that in a combined form brought to it by the rain.

The publication of the original paper of Berthelot, presented to the Academy of Sciences on October 24, 1885,[2] led Joulie[3] to make a report of the experiments conducted by him, which show a certain increment of nitrogen in cultivated soils. The soils used were of a clay-sand nature from the Dombe (Ain).

On the 30th of June, 1883, there were placed in each of the experimental pots six sprouted buckwheat grains.

On the 6th of September the plants were gathered, by cutting them off even with the ground. The roots were left in the soil. On the 15th of September the pots were sown with a mixture of ray-grass and clover. The pots being kept in a hot house, the harvest of these grasses took place in March, 1884. A second crop of the same grasses was gathered on the 18th of June, 1884; a final cutting was made on August 21, 1884.

If the soil in a hectare of the same depth as in the experimental pots weighs 2,000 metric tons, the gain in nitrogen, as indicated by the experiments, would be 1144 kg. Calculated wholly on the surface exposed, and taking into account the weight of the soil, the gain would have been 432 kg. per hectare. M. Joulie adds, that we should not be in too great a hurry to estimate the value of this increment, because the greater part of the nitrogen fixed is in a form ill suited to assimilation by plants. In a second series of experiments, commenced in May, 1884, there was a gain of nitrogen in every case but one. This gain was not as great as in the first series, but nevertheless distinct. The experiment, however, was not continued as long as in the first case, having terminated on the 16th of September, 1884. After discussing the various sources of

[1] Mayer, Agriculturchemie, 3d ed., 1886, p. 199.
[2] Comptes Rendus, Vol. CI, p. 775.
[3] Ann. Agronomiques, Vol. XII, No. 1, pp. 5 *et seq.*

the increase, M. Joulie concludes that it could only have come from the free nitrogen of the air.

M. Joulie's second set of experiments were made in sand. For this reason, he is disposed to doubt M. Berthelot's assertions that the microbes which cause this fixation are peculiar to a clayey soil. M. Joulie, admitting that such organisms may and do enable the free nitrogen to become fixed in the soil, claims further that the plant itself may take part in this operation. He thus raises again the old contested question over which there has already been so much warm discussion. It would be rather strange, after so many years, if science should at last return to the conclusions of Ville.[1] M. Joulie calls attention to the fact pointed out by Thénard, that by means of the electrical discharge free nitrogen could be combined with the elements of water. He adds, that it is well known that oxygen set free by living leaves, and resulting from the decomposition of the carbonic acid, is ozonized, that is, electrified. Thus there are produced in the living plant electrical phenomena analogous to those which enabled the Thénards to perform the remarkable experiments already mentioned. The fixation of nitrogen by plants, admitted by agriculturists and by some scientists, is not therefore an opinion without foundation, as some great scientific authorities affirm. In a further study of the results of his experiments, M. Joulie concludes that the application of lime is especially favorable to the fixation of nitrogen by the growing plant. On the contrary, the use of manure and of dried blood diminishes the capacity of the plant for fixing nitrogen, and even in some cases destroys it. But the addition of carbonate of lime in excess to the manure favors the fixation of the free nitrogen.

One of the most interesting conclusions reached by Joulie is, that mineral fertilizers, deprived of phosphoric acid or of potash, seem to diminish, and even destroy, the ability of the growing plant to assimilate free nitrogen.

In conclusion, M. Joulie says :—

"The microbes seem to play an important rôle in this matter, even in the absence of clay, since we obtain a marked fixation in experiment No. 1, of the second series, where there is no clay, and almost no vegetable matter. As to the intervention of plants, these few experiments do not appear to establish it, although they

[1]Comptes Rendus, Vol. XXXV, p. 464; XXXVIII, pp. 705–723; and XLI, p. 757.

do not authorize a direct contradiction of it. This is a point which calls for new studies, and on which some comparative experiments, with and without vegetation, would be certainly able to throw much light."

In the light of the investigations of the last few years, it may be well to admit that the opinion held by the vast majority of agronomists and agricultural chemists and physiologists, that the free nitrogen of the atmosphere never is assimilated by the growing plant, should be held open for revision.

The general belief among scientific men who have paid attention to this matter has inclined to the opinion of Lawes and Gilbert, Pugh, and Boussingault,—that the growing plant does not, in any circumstances, assimilate the free nitrogen of the air. So widespread was this opinion, that before the investigations just noticed, when Atwater[1] published a series of experiments showing the contrary, it was thought some factor in the investigation had been overlooked. According to Atwater's results, it appears that "the plants grown in nutritive solutions exposed to the air, but protected from rain and dew, contained at maturity much more nitrogen than was supplied them in nutritive solution and seed."

This is certainly a definite and unequivocal statement; and it was followed by "for this excess of nitrogen there was but one possible source, namely, the atmosphere."

In respect of the quantity of free nitrogen thus assimilated by the plants, Atwater gives 127 kg. per hectare, amounting to not less than 47 per cent of the total nitrogen in the plant. For the details of these highly interesting studies by Atwater I must content myself to cite the original paper.

7. *Mineral Nitrates.*

A dry climate is indispensable to the accumulation of mineral nitrates (*e. g.*, nitrate of soda), since all of them are easily soluble in water. Their occurrence in the United States would, therefore, be looked for only in the arid regions of the southwest.

A deposit of Chili saltpetre (sodium nitrate) has lately been found in Humboldt County, Nevada.[2] The annual rainfall in this part of Nevada is only four inches; but this is even more than oc-

[1] Am. Chem. Jour., Vol. VI, pp. 365 *et seq.*
[2] Williams, Min. Resources, 1882, p. 599.

curs in Chili and Peru, where the greatest nitrate beds of the world are found. Nitrate of soda has also been found in San Bernardino County, California; but the extent of these deposits is not yet known. Deposits of this salt are also found in southern New Mexico, and in Chihuahua, Mexico.

The nitrate beds of Peru (now occupied by Chili) are found in the district of Tarapaca, where the dry pampa for a distance of forty leagues is covered to a depth of several feet with a bed of this salt.[1]

The quantity of Chili saltpetre imported into the United States has slightly diminished in the last two years.[2]

In 1882	it was	184,554,374 lbs.,	worth	$3,911,544
In 1884	"	121,202,296 "	"	1,983,378
In 1885	"	109,361,808 "	"	1,696,056

All this quantity, however, was not used directly in fertilizers, part of it having been used in the manufacture of nitre.

In respect of the method in which the nitrogen entered into the formation of these mineral nitrates, a theory has already been given. Nitrate of potash, although more valuable as a fertilizer than the corresponding soda salt, is, on account of its limited occurrence and high price, not extensively used for this purpose.

The remarkable investigations in nitrification, an abstract of which I have just presented, have led me to attach a new worth to the value of nitrates as plant food. They have also led experimenters to enquire whether nitric nitrogen might not be found largely distributed in plants as such, as well as after having been elaborated into protein products. A few years ago it was thought that the distribution of nitrates was very limited, being confined to a few plants and restricted to certain parts thereof.

Arnaud and Padé,[3] having discovered an alkaloid, cinchonamine, which has the remarkable property of forming an insoluble salt with nitric acid, were able to detect the presence of nitrates in various plants. Thin sections of these plants, placed in a solution of cinchonamine acidulated with hydrochloric acid, and thereafter examined with a lens, showed numerous adhering crystals of a cinchonaminic nitrate. Nitrates were thus discovered in *Parietaria*

[1] Ibid.
[2] Com. and Nav. U. S., 1885, p. 575.
[3] Comptes Rendus, Vol. XCVIII, p. 1188.

officinalis, *Borrago officinalis*, *Digitalis purpurea*, *Chenopodium murale*, *Solanum tuberosum*, *Urtica ureus*, *etc.*

As has long been known, nitre is present in considerable quantities in sugar beets and allied plants, and the osmogenes in use in the sugar factories in Europe show how eager the operators are to be rid of this highly melassigenic material.

Even as long ago as 1747, Sachs[1] pointed out the existence of nitre in tobacco, wall pellitory, and fumitory (*Fumaria officinalis*).

Pursuing the study at the Agricultural Chemical Station at Meudon, Berthelot has shown practically the universal presence of nitrates in plants. This general occurrence of nitrates gives a new economical value to the nitrifying ferment.

Berthelot and André [2] make a further study of the occurrence of nitrates in the different parts of plants, and also give the methods of estimating the nitrogen thus combined, a method which consists essentially in extracting the nitrates by sixty per cent alcohol, and determining the nitrogen after evaporation of the spirit by Schlösing's method. They show further,[3] that the percentage of nitrates increases in the growing plant (notably in borage), up to the commencement of florescence. During the period of seed formation nitrates diminished in quantity, being presumably used in the formation of albuminoids. Afterwards the quantity of nitric nitrogen again increases. In respect of the distribution of the nitre, they show[4] that the stalks of the plant contain most of it; next, the roots; and, last of all, the leaves and seed.

As to the actual weight of nitre produced per hectare, Berthelot and André[5] give some interesting facts. The plants which seem to be most nitrifacient, and the quantities of potassium nitrate furnished by them per hectare, are given in the following table:—

Borago officinalis	120 kg.	KNO^3
Amarantus bicolor	128 "	"
Amarantus caudatus	140 "	"
Amarantus pyramidalis	163 "	"
Amarantus giganteus	320 "	"

It appeared from the analysis of the soil before and after the crop that the nitrogen in the above was derived chiefly from the soil.

[1] Fundamenta Chymicæ, Pars II, p. 105.
[2] Comptes Rendus, Vol. XCIX, pp. 355 *et seq.*
[3] Ibid., pp. 550 *et seq.*
[4] Ibid., pp. 591 *et seq.* [5] Ibid., pp. 683 *et seq.*

The authors say, however: "The atmosphere perhaps furnished some of it, in the form of ammonia or nitric acid possibly also of free nitrogen, a question which we will reserve for the moment."

Of interest also in this connection is the ammoniacal ferment described by Ladureau,[1] which exists in the atmosphere and the soil, and which is especially active in transforming urea into ammonia, and thus fitting it for nitrification and absorption by the plant. Ladureau announces that he is seeking for a body that will temporarily destroy the activity of this ferment, so that the urea of barn-yard manures, etc., may be preserved from conversion into ammonia until such time as the plant may most need it. Chloroform retards the action of the ferment, but ordinary antiseptics, unless used in large quantities, do not. It must be confessed that a means of arresting this fermentation in the manner indicated would prove of immense value to the agriculture of the world.

In further discussing the origin of this large amount of nitric nitrogen in the plants, the authors come to the conclusion that it is not all furnished (as nitrate) either from the soil or from the rain-waters, but that its formation is a function of the plant itself, analogous to the nitrification which takes place in the soil by the action of the ferment described by Schlösing and Müntz. Those parts of the plant which are the seats of the most vigorous oxidations, viz., the cells of the stalk deprived of light, are the localities where nitrogen is most rapidly converted to the nitric form, while the leaves and parts exposed to the light, the chlorophyll-reducing organs produce the opposite effect. In other words, the formation of nitric acid takes place in a manner entirely analogous to that of carbonic, oxalic, tartaric, malic, citric, and other highly oxidized acids.

These views of chemists so distinguished, based as they are on a series of experiments, extended and laborious, even if not above criticism, must command our most serious attention. They expressly admit the possibility of the use of free nitrogen of the atmosphere, but are careful not to literally affirm it.

It is due to M. Leplay to call attention to the claim he makes to priority in the discovery of large numbers of the facts mentioned above, which he sets forth in detail in answer to MM. Berthelot and André,[2] and the answer of these chemists thereto.[3]

[1] Comptes Rendus, Vol. XCIX, p. 877. [2] Ibid., pp. 925 *et seq.* [3] Ibid., pp. 949, 950.

From the foregoing studies the following general conclusions may be drawn:—

1. The combined nitrogen which is the product of vegetable and organic life forms the chief source of nitrogen for the growing plant.

2. Before it is assimilable by the plant, it undergoes a process of oxidation, which is due solely to a living organism.

3. The nitrates thus formed are absorbed by the plant, and the albuminoids of the new growth are formed from the nitric nitrogen by a process of reduction. The nitrates themselves are subject to the action of a ferment by which a deoxidation takes place and free nitrogen and nitrous oxide are evolved.

4. The diminution in the quantity of available nitrogen thus supplied is restored by the fixation of free nitrogen by the action of organisms in the soil, or by the oxidation of free nitrogen by the interior cells of the plant acting in a manner analogous to the nitric ferment in the soil, or by the oxidation of free nitrogen by electrical discharges or by combustion.

5. The quantity of combined nitrogen brought to the soil and growing plant by the rain-water and the atmosphere, arising from the last two phenomena, is an inconsiderable amount when compared with the whole weight required by the crop.

FUTURE FOOD SUPPLY.

Since, with a proper economy, the natural supplies of potash and phosphoric acid, as we have seen, may be made to do duty over and over again, and last indefinitely, the economist who looks to the welfare of the future need have no fear of the failure of these resources of the growing plant. Indeed, it may be said, that the available quantities of them may be increased by a wise practice of agriculture based on the teachings of agricultural chemistry.

But with the increase of population comes an increased demand for food, and therefore the stores of available nitrogen must be enlarged to supply the demands of the increased agricultural product. It is certain, that, with the new analytical methods, and the new questions raised by the investigations of which I have spoken, many series of experiments will be undertaken, the outcome of which will definitely settle the question of the entrance of free nitrogen into vegetable tissues. If this question be answered

affirmatively, agricultural science will not place bounds to the possible production of foods. If the nitrifying process does go on within the cells of plants, and if living organisms do fix free nitrogen in the soil in a form in which at least a portion of it may be nitrified, we may expect to see the quantities of combined nitrogen increase *pari passu* with the needs of plant life.

Thus even intensive culture may leave the gardens and spread over the fields, and the quantities of food suitable for the sustenance of the human race be enormously increased. In regarding the agricultural economies of the future, however, it must not be forgotten that a certain degree of warmth is as necessary to plant development as potash, phosphoric acid and nitrogen.

If it be true, therefore, that the earth is gradually cooling, there may come a time when a cosmic athermacy may cause the famine which scientific agriculture will have prevented.

Fortunately, however, for the human race, the cereals, the best single article of food, are peculiarly suitable to a cold climate. Barley is cultivated in Iceland, and oatmeal feeds the best brain and muscle of the world in the high latitudes of Europe.

It is probably true that all life, vegetable and animal, had its origin in the boreal circumpolar regions. Life has already been pushed half-way to the equator, and slowly but surely the armies of ice advance their lines. The march of the human race equatorwards is a forced march, even it it be no more than a millimeter in a millennium.

Some time in the remote future the last man will reach the equator. There, with the mocking disk of the sun in the zenith, denying him warmth, flat-headed and pinched as to every feature, he will gulp his last mite of albuminoids in his oatmeal, and close his struggle with an indurate inhospitality.

PAPERS READ.

PRELIMINARY ANALYSIS OF A HONDURAS PLANT NAMED "CHICHIPATE." By Miss HELEN C. DE S. ABBOTT, Philadelphia, Pa.

A PROBLEM IN CHEMICAL BIBLIOGRAPHY. By Dr. H. CARRINGTON BOLTON, Trinity College, Hartford, Conn.

ACTION OF HEAT ON ETHYLENE.[1] By Prof. L. M. NORTON, Institute of Technology, Boston, Mass.

REPORT ON METHODS OF STATING WATER ANALYSES.[2] WASHINGTON CHEMICAL SOCIETY. A. C. PEALE, W. H. SEAMAN, C H. WHITE, } *Committee Washington Chemical Society.*

THE TORSION ANALYTICAL BALANCE. By Dr. ALFRED SPRINGER, Cincinnati, O.

DETERMINATION OF NITROGEN IN COMMERCIAL FERTILIZERS. By B. B. ROSS and L. W. WILKINSON.

ON THE MELTING POINT OF FATS. By Prof. H. W. WILEY, U. S. Department of Agriculture, Washington, D. C.

ON SOME LAWS OF CHEMICAL UNION. By C. F. DELAUDERO and PAUL PRIETO, Guadalajara, Mexico.

ON THE AREOMETRIC METHOD OF ESTIMATING FAT IN MILK. By Prof. H. W. WILEY, Department of Agriculture, Washington, D. C.

NOTES ON THE COMPOSITION OF SOILING-RYE. By Prof. WILLIAM FREAR, State College, Pa.

PRELIMINARY ANALYSIS OF THE LEAVES OF JUGLANS NIGRA.[3] By Miss LILLIE J. MARTIN, Indianapolis, Ind.

TYROTOXICON (CHEESE POISON), ITS OCCURRENCE IN MILK, AND ITS PRODUCTS AND THE METHODS OF DETECTING IT.[4] By Dr. V. C. VAUGHAN, Ann Arbor, Mich.

PNEUMATIC PROCESS CONVERTING SODIUM CHLORIDE AND SULPHATE, INTO SODIUM CARBONATE BY MEANS OF THE OXIDES OF CARBON. By ADOLF KAYSER, Buffalo, N. Y. Presented by ALBERT B. YOUNG.

[1] Am. Chem. Jour., *8*, 362–364. [2] Nature, *33*, 546; Chem.News, *53*, 186.
[3] Am. J. Pharm., *58*, 468–474. [4] Rep. of Proc. Mich. State Board of Health, July 13, 1886.

THE COMPOSITION OF CERTAIN WELL WATERS CONTAINING LITHIUM IN CLEVELAND. By Prof. C. F. MABERY, Case School of Applied Science, Cleveland, Ohio.

ON CERTAIN SUBSTITUTED ACRYLIC AND PROPIONIC ACIDS. By Prof. C. F. MABERY, Case School of Applied Science, Cleveland, Ohio.

ON THE COMPOSITION OF CERTAIN PRODUCTS FROM THE COWLES ELECTRICAL FURNACE.[1] By Prof. C. F. MABERY, Case School of Applied Science, Cleveland, Ohio.

A NEW VISCOMETER. By S. M. BABCOCK, Geneva, N. Y.

BLUE MILK AND ROPY CREAM. By Prof. WM. McMURTRIE, Champaign, Ill.

CERTAIN CHEMICAL CONSTITUENTS OF PLANTS, CONSIDERED IN RELATION TO THEIR MORPHOLOGY AND EVOLUTION.[2] By Miss HELEN C. DE S. ABBOTT, Phila., Pa.

THE NON-PRECIPITATION OF LEAD SALTS BY MERCURIC CHLORIDE. By Prof. O. C. JOHNSON, Ann Arbor, Mich.

THE QUANTITY OF ARSENIC CONTAINED IN COMMON WALL PAPER. By Prof. HENRY CARMICHAEL, Brunswick, Me.

CERTAIN NEW METHODS OF FILTRATION. By Prof. HENRY CARMICHAEL, Brunswick, Me.

THE COPPER REDUCTION TEST FOR THE QUANTITATIVE ESTIMATION OF ARSENIC.[3] By Prof. HENRY CARMICHAEL, Brunswick, Me.

CONTRIBUTIONS TO THE CRYSTALLOGRAPHY OF ANIMAL AND VEGETABLE FATS.[4] By THOMAS TAYLOR, M.D., Microscopist U. S. Dept. of Agriculture, Washington, D. C.

ON THE PRESENCE OF CANE SUGAR AND ALLANTOIN IN THE UNGERMINATED EMBRYO OF WHEAT.[5] By CLIFFORD RICHARDSON and C. A. CRAMPTON, U. S. Agricultural Dept., Washington, D. C.

THE CONSTRUCTION OF CHEMICAL LABORATORIES. By Prof. W. H. CHANDLER, Lehigh Univ., South Bethlehem, Pa.

THE RELATIONS OF AIR AND WATER. By Prof. WM. H. PITT, Buffalo, N. Y.

DETERMINATION OF CAFFEINE. By W. HODGSON ELLIS, Toronto, Canada.

VISCOSITY OF FATS AND OILS. By E. H. S. BAILEY, Lawrence, Kans.

THE IMPORTANCE OF ULTIMATE ANALYSES OF COAL OVER PROXIMATE ANALYSES IN CALORIFIC DETERMINATIONS. By Prof. OLIN H. LANDRETH, Vanderbilt University, Nashville, Tenn.

[1] Jour. Frank. Inst., *122*, 271-274. [2] Bot. Gaz., *11*, 270-272.
[3] Am. J. Sci., [3] *32*, 129-132. [4] Rep. of N. S. Dept. Agriculture. [5] Berichte, *19*, 1180-1181.

SECTION D.

MECHANICAL SCIENCE

AND

ENGINEERING.

ADDRESS

BY

O. CHANUTE.

VICE PRESIDENT OF SECTION D.

SCIENTIFIC INVENTION.

MEMBERS OF THE SECTION OF MECHANICAL SCIENCE AND ENGINEERING:

THE enlarged scope given last year to Section D of the American Association for the Advancement of Science, so as to cause it to embrace the whole of engineering and of mechanical science, and the steadily growing interest manifested in its meetings, warrant you in expecting, upon this occasion, some remarks upon the results which it may fairly be expected to accomplish, and possibly some hints as to the ways by which it may be made even more useful in the future in advancing scientific knowledge and methods.

I have therefore selected as the subject of this address, the progress of "scientific invention," and shall endeavor to point out how dependent men are upon each other, in developing abstract scientific knowledge or discoveries into useful appliances or inventions, and how attendance upon these meetings may result not only in enlarging knowledge, but in valuable developments in the practical affairs of life. I shall also endeavor to be brief.

The age in which we live is evidently one of material development. Other periods have heretofore been marked by human activity in other directions, which for the time attracted to themselves the contemporaneous natural leaders of the generation. There have been times when philosophy and pure art chiefly engrossed the thoughts of the brightest minds and the most highly gifted men then living; times of religious fervor and crusades; periods of wars and conquests, and again of exploration and colonization; periods

also of political changes and remodelling, when the greatest minds were engrossed by the affairs of the state; but, for the past one hundred years, the attention of the leading men, in what we deem to be the civilized world, has chiefly been directed to the increasing and cheapening of the production of all of those things which minister to the daily life and comfort of men.

Both public and private effort, therefore, are directed to material development and to increased well-being. The farmer, the mechanic and the laborer wish to live, and do live, notwithstanding the assertions of those who are always dissatisfied, more comfortably than did the middle classes in the old feudal times; the average duration of human life has been materially lengthened, and all portions of society have ever present in mind the desire still further to add to this material progress, by some improvement in organization or by some fortunate invention.

This great material progress may be said to have set in with the final perfecting of the steam engine, which—together with various resulting machines to take the place of animal and hand labor—has increased so many fold the productive powers of man, and cheapened so greatly the necessaries and luxuries of life. Under such a condition of affairs, the builders and managers of industrial operations, the organizers of labor, the inventors, the engineers and the mechanicians naturally become the leaders of modern industry.

Invention, therefore, plays a great part upon the modern stage. It needs no argument to point out the services it renders to modern society, but it may be useful to point out how indispensable to its success is verbal and written intercourse between its votaries, how it advances step by step, and how the scientific speculation and curiosity of the investigator become the effective invention of the constructor.

Nothing is more remarkable in the field of invention, than the multitude of minds and facts which are required to perfect even the most simple design or machine, nor how little comparatively the last successful man has added to the stock of preëxisting knowledge. Certain facts and natural laws may be known for years, first as curious discoveries and principles, and no one may see how they can be utilized in the daily affairs of life. Then some inventor will try to turn them to some practical use, and very likely he will fail. Then a second genius will take up the subject and if he

has been fortunate enough to learn the causes of the first man's failure, he may produce a machine which will work, but which costs too much to operate and to keep in repair to come into general use. At last the successful man appears, who, instructed by the mistakes of his predecessors, works out a practical design, and either making or losing a fortune yet adds materially to the well-being and comfort of the whole of mankind.

It is given to but few men both to discover and to invent. The faculties appear to be separate and distinct. One set of men, of a scientific turn of mind observe facts, and deduce therefrom the natural laws which govern them. They announce their discoveries and describe their experiments, largely as we hope hereafter in this Section of Engineering and Mechanical Science, and then another set of men go through the sometimes heart-sickening labor, of turning these discoveries to practical account by basing thereon designs for labor-saving appliances.

For the sake of pure science, many of the men whom I now see before me are devoting their lives to the study of nature. They gather knowledge everywhere, they patiently observe facts ; they try many fruitless experiments, and they treasure up curious and apparently irrelevant observations for the mere purpose of increasing their knowledge. All the time which they can spare from the avocation which gives them their daily bread is devoted to their favorite pursuit ; not with the mean hope of eventually making money out of it, but with the wish to increase human knowledge, and possibly of being repaid with reputation. Sometimes they are rewarded by the discovery of some hitherto unknown fact or law, some new observation or combination, which makes their name famous among scientific men, and which eventually assumes practical shape by being turned to the use and convenience of man.

Sometimes, indeed I may say generally, it happens that the facts and laws upon which an important invention is based are known for a long time before they are applied to practical use. The stones are quarried from the treasure-house of nature, they are described and catalogued, but no use is made of them, until the architect of the invention appears, and by some happy conception combines them into a monument for all time.

All history of invention proves that the scientific men, whom I have alluded to as the observers, have the safer and the happier part. Their success may not be as dazzling as that of a few great

inventors, but they do not have to bear the bitter trials and disappointments of the men who try to evolve a new invention, unless indeed they try to become inventors themselves, and then they generally fail.

There seems to be a great difference between the capacity for scientific investigation and the inventive faculty. The first gathers facts, observes experiments and deduces natural laws. This requires mental accuracy in observing and reasoning. The second combines these facts, organizes them into new relations, and endeavors to put them to daily work. This requires imagination and ingenuity. One class of minds observes and another class invents, and if the latter sometimes draws the greater prizes, its failure and disappointments are also much the more numerous and severe. Sometimes long years pass and generation after generation of inventors are worn out, before a machine, the need of which is universally recognized, becomes an accomplished success. It is evident therefore, that the more minds can be brought to bear upon the solution of a particular problem, the more information and suggestions can be exchanged, the greater will be the chance of an early solution of that problem.

I believe that it is the particular province of this section of the American Association for the Advancement of Science, to endeavor to bring these two classes of mind together, to promote their intercourse and exchange of views, in order on the one hand that the inventors may be advised as to what is discovered and known, and on the other that the observers shall know in what directions fresh information is needed, what new inventions and appliances are in the air, and thus enable both classes of minds to accomplish the best results for civilization.

To make my meaning more clear, that invention does not spring full-armed from the brain of man, I may be permitted to digress so far as to relate again the history of some few great inventions, and of the difficulties which were encountered for lack of just such an association as this.

And first let me take, with due apology to this assemblage, the well-worn history of the steam engine, the machine of all others, which, as before stated, has done more for the world than any other invention of modern times.

I compile the following from Smiles' life of Watts.

About two thousand years ago, Hero of Alexandria gave a de-

scription, in his treatise on Pneumatics, of the first steam engine or Æolipile. This consisted of a jet of live steam impinging upon rotating vanes, much after the fashion of an overshot water wheel.

This treatise remained hidden in manuscript during the dark ages, until a translation was printed in 1547, when attention was attracted to the subject, and Branca the Italian architect constructed an Æolipile for pounding drugs.

Hero's book, of which eight different editions in different languages were printed within a century, attracted the attention of Solomon de Caus, a French architect and inventor, and inspired him to try experiments and to invent an apparatus for raising water from a closed vessel by the pressure of steam upon it. These experiments did not succeed in making a working steam engine of any kind, but they probably were known to the next inventor, the Marquis of Worcester, either prior to 1615 when De Caus was in exile in England, or after 1646 when the Marquis took refuge in France from his political enemies.

At any rate Solomon De Caus failed, although modern research seems to show that there is no truth in the touching story that he was shut up in a mad house for claiming to have invented a new power, and the Marquis of Worcester, second of the name, took up the subject. He was an inventor, and scattered his ingenuity over many things, but he considered his "Water Commanding Engine" the greatest of them all; and in 1663, at the age of 62, he erected one in London, which was described by various foreigners, in their accounts of their visits to England.

The Marquis claimed to have spent about $250,000 in his various experiments, but his steam engine did not prove a success. It raised with the aid of one man, "four large buckets of water to a height of forty feet, within a minute of time through a pipe eight inches in diameter," but although a great advance upon what De Caus had accomplished, it was not considered more effective or cheaper than animal power. The Marquis of Worcester got into financial difficulties and died in 1667 a disappointed man.

Undeterred by his fate, Sir Samuel Morland, also an inventor of many things, "in 1667 took a lease of Vauxhall, most probably the identical house occupied by the Marquis of Worcester, where he conducted a series of experiments as to the power requisite to raise water by cylinders of different dimensions."

This indicates a considerable advance in the elimination of unsuccessful devices. The direct steam jet was early discarded, De Caus and the Marquis of Worcester had tried direct steam pressure upon the water to be raised and they had failed, and Sir Samuel Morland experimented with cylinders. He, however, accomplished no greater success. His later years were spent in poverty and blindness, and he died in 1695.

The next prominent experimenter was Dr. Dionysius Papin, a protestant French physician, who in 1681 took refuge in London from religious persecution.

Being a prominent scientific man, he was probably aware of the previous experiments with steam, and when he was appointed curator of the Royal Society of England, at the meetings of which it was his duty to produce experiments, he exhibited his well known "Digester" in which high temperatures were produced by confined steam pressure. This, although a backward step, led him to make further experiments, and eventually "he clearly perceived that a piston might be raised in a cylinder by the elastic force of steam, and that on the production of a vacuum by its condensation, the piston might be driven home again by the pressure of the atmosphere." His efforts, however, to build practical engines failed, both in France and Germany where he undertook to drain mines by steam power; and finally, in 1707, when after fifteen years' labor he had succeeded in constructing a model engine, fitted in a small boat, and had started it from Germany for exhibition on the Thames, it was seized by the boatman of Münden and barbarously destroyed.

The machine must have been a doubtful success; for, Papin's means being exhausted, he made urgent appeals to his friends to advance him funds to construct another engine, and they failed to respond. Two years later, "worn out by work and by anxiety" he died, leaving to others the dismal task of taking up the evolution of the steam engine.

This was assumed by Thomas Savery, "who is usually accorded the merit of having constructed the first actual working steam engine." He obtained a patent in 1698 and for the next few years endeavored to introduce it for pumping out various mines, but although he built a number of such engines in various localities, they proved too cumbrous, dangerous and expensive in the working, and were finally abandoned.

This probably arose from the fact that Savery had gone back to

the plan of having direct steam pressure (and the consequent condensation) upon the body of water to be raised, instead of interposing a piston as was subsequently done by Thomas Newcomen. The latter was well aware of Savery's labors, so much so that he eventually agreed to give him an interest in his own engine. During the term of Savery's patent, and at last "after long scheming and many failures he at length succeeded in 1705 in contriving a model that worked with tolerable precision." This consisted in the so-called atmospheric engine, in which a piston was raised by the elastic force of steam to the top of a cylinder, when by the condensation of the steam by a jet of cold water, a partial vacuum was formed beneath the piston, and the latter was forced down by atmospheric pressure.

This steam engine was the first to go into practical use, and between 1705 and 1758 quite a number were erected, but it was wasteful of steam, and consequently of fuel, so that in certain localities where coal was expensive, it was found to raise water at no economy over animal power. Its duty was estimated at the raising of five and a half millions of pounds one foot high per bushel of coal burned, while the subsequent improvements of James Watt eventually increased the duty of the steam engine to the raising of sixty millions of pounds one foot high per bushel burned.

With the career of Watt all are familiar. How, establishing himself in Glasgow in 1757 as a mathematical instrument-maker, a model of a Newcomen engine, belonging to the museum of the University, was placed in his hands for repair. How he studied its defects and its possibilities, and how devoting his whole subsequent life to the subject, he succeeded after twenty years of labor and disappointments in making a mechanical and financial success of the steam engine, are of course present in your memories.

The two observations to which I wish to call your attention, as resulting from the inspection of this bare skeleton of history, are first the gradual evolution of the invention by the process of exclusion, by finding out what would not do, and second the apparent chain of connection running for over a century through several generations of inventors, each evidently profiting by the failures of his predecessors, to the extent at least of avoiding their repetition.

It is not evident that the earlier inventors would have accomplished greater results if they had had a larger range of scientific experiments and advice, and that Watt, the last successful man,

triumphed in great measure because he had the whole faculty of the University of Glasgow at his back, to give him knowledge of natural principles, and information as to what had been done.

The history of almost all important inventions exhibits the same characteristics of gradual development through the efforts of many inventors, and impresses us with the vast amount of toil and study necessary for success. Whether we consider the history of the steamboat, from 1760 to 1807, with its many experimenters, or that of the locomotive from 1802 to 1829; or that of the telegraph from 1729 to 1844, when finally the scientific discoveries of others were put to practical use by Professor Morse; or that of the sewing machine from 1790 to 1860, with its many inventors and 2000 patents; or that of the reaping machine which took seventy-five years of persistent efforts of various inventors for its evolution; or that of spinning machinery with its multitude of gradual improvements; we invariably find that it has taken many men to bring the invention to perfection, that the last successful man has generally added but little to what was previously known, and that, as a rule, the basis of his success lay in a thorough acquaintance with what had been done before him, and in his setting about his work of improvement in a thoroughly scientific way.

I might go on indefinitely in this direction, and compile from well-known authorities similar instances of the scientific development of various modern inventions, but I prefer to relate a few facts which have come to my personal knowledge, concerning one phase of the development of what is probably one of the latest inventions, that of machines for producing cold artificially.

It had long been known through the researches of chemists that heat and cold were merely interchangeable conditions of matter, and that inasmuch as one pound of coal contains about one hundred times as many thermal units as one pound of ice, cold could theoretically be produced from fuel, in many cases, more economically than by the use of natural ice, if only the proper methods and mediums were used.

Such a medium had been indicated by Professor Cullen's experiments in Glasgow in 1755 in producing cold by the evaporation of various volatile substances, the most powerful of which he found to be the "quicklime spirit of sal ammoniac."

Professor Cullen's discovery had however remained a laboratory experiment until Jacob Perkins constructed an apparatus for pro-

ducing ice and cooling liquids, by the use of ether, in 1834. This proved a partial success, but was abandoned for other pursuits; and subsequently the subject was taken up, and various substances used, by many experimenters, among whom may be mentioned Professor Alexander C. Twinning of New Haven in this country, and Leslie, Valance, Harrison, Pontifex, Seibe, Windhausen, Tellier, Carré and Pictet abroad, with more or less doubtful success.

Prior to 1869, however, it may be said that there were no really successful refrigerating machines in operation. There were a number of experimental machines, of which great things were expected, but they constantly broke down and gave trouble. They were passing through the perils of infancy. In that year, a merchant formerly doing business in the south found himself stranded in San Francisco with some money, and a strong desire to possess an ice-making machine. He had journeyed thither to purchase one which did not come up to his expectations; he had ordered another from England which the makers failed to furnish, and he tried in various directions to buy a successful machine, only to find himself disappointed, until at last, in desperation of obtaining what he wished, he made up his mind to invent a machine for himself.

He went about it in the scientific way. Gaining access to the technical library of the Mechanics' Institute of San Francisco, he deliberately set to work to read up all that was known on the subject of refrigeration, going through every volume likely to have a paragraph relating to ice machines, and teaching himself the theory of the subject. He spent ten or twelve hours a day in that library, learning what patent attorneys call "the state of the art," as well as the results of various experiments, and the principles which underlaid them.

In relating this experience, he said to me that he never worked so hard before or since in his life.

He, however, had a fair reward; for, having discarded the use of ether, of sulphur dioxide, and of liquid ammonia, which were then the favorite substances used in various machines, he determined to produce cold by pumping anhydrous ammonia, or ammoniacal gas deprived of its water, and devised machinery for that purpose.

He successively built two experimental machines, which gave him promise of future success, took out a patent in 1872, and by this time, his capital being nearly all exhausted, he removed to

New Orleans to offer his improvements to the Louisiana Ice Manufacturing Co. This being declined he finally built a machine on his own account, and after struggling with various difficulties put it into successful operation at Jefferson, Texas, in the spring of 1874.

Since then the machine has become one of the leading competitors in favor for making ice in warm climates and for cooling meat-packing establishments and breweries, the latter especially proving willing purchasers.

But the development of the machine did not stop there. There was in 1877 in New York city a brewer, who had made up his mind that he wanted a refrigerating machine in his brewery. He investigated the merits of the various machines then upon the market, and having a clever chemist associated with him, he tried experiments to ascertain their efficiency. He satisfied himself that those compressing (or pumping) anhydrous ammonia were the best, but that they gave results of only about 70 per cent of their theoretical efficiency. He set about in a deliberate attempt to improve this, and in addition to the chemist he called to his aid a practical mechanic and a patent expert. The latter made a digest of all the patents issued up to that time on the subject showing the state of the art, the mechanic devised the machine and the chemist tried experiments.

The difficulties to be overcome were in the pump, or compressor. As a clearance must necessarily be left between the piston and the cylinder head, only a portion of the ammoniacal gas was expelled at each stroke. The portion remaining in the cylinder reëxpanded with the reverse motion of the piston and was churned uselessly up and down. The ammoniacal gas, being very searching, also leaked past the stuffing box, and was lost.

It was proposed to remedy these defects by using a lubricating fluid to form a seal for the piston and stuffing box, and after making many drawings, a machine was ordered and built in 1878; and put into operation in the brewery in which the inventor was interested.

He says of this machine: "Tests were made to prove its efficiency, and after many days of anxious labor in this direction, he was forced to the conclusion that the time, money and thought had been expended to very little purpose. The pump would compress no greater percentage of gas than those previously made, conse-

quently would perform no more work, and the experiment was finally abandoned.

The inventor, not being satisfied to let the matter rest here, after some weeks of thought and consultation, determined to devise and, if possible, to put in operation, another machine which would avoid and overcome the difficulties encountered in the first attempt. New plans were accordingly made, and another machine built."

This second attempt proved more fortunate than such matters generally do, for this machine, built in 1880, was entirely successful, cooled the brewery to better advantage than was previously done by the use of 7000 tons of natural ice, and has become the precursor of many similar machines which are now working economically in various parts of the country.

I may add that so rapid has been the development of this new industry, that there are now several hundred refrigerating machines of various makes at work in the United States, and that they are rapidly superseding the use of natural ice in large establishments. They produce cold, at a rate equivalent to about twenty tons of ice melted for each ton of coal consumed, and at a cost including every expense, as that of fuel, attendance, cooling water, lubrication, repairs, wear and tear, and interest upon the plant (which is very costly), equivalent to natural ice at seventy-five or eighty cents a ton, which is less than it can be harvested for and stored in such establishments in most sections of the country.

I have related this episode, in contrast with the history of the steam engine, to illustrate the difference between the scientific method of working out an invention, and the former disjointed way in which each man had chiefly to rely upon his own experiments; and also to illustrate the difference between the ancient facilities and the modern advantages offered by present organizations, whether of experts, of publications or of scientific societies.

Similar instances are probably within the knowledge of most of you. You know that important results are seldom accomplished by the intuition of one man. That he must be aided by others, and that information is so widely scattered, and covers so many different fields of science, that it is only by patient effort and much searching that the needed knowledge is gained.

To you and such as you, the meetings of this association manifest their great importance.

In addition to the current knowledge acquired, they afford an

opportunity once a year of hearing and discussing papers upon the application of scientific methods to every department of engineering, and of resolving any doubts or queries by meeting at one time a large number of men eminent in various branches of science to which engineering is closely related.

I have heretofore alluded to the builders and managers of industrial operations, the organizers of labor, the inventors, the engineers and the mechanicians as the leaders of modern industry, and I now wish to point out why this association may be made most useful to them. They have, to be sure, access to the text-book, to many excellent publications relating to their business, and to a number of flourishing technical societies. These latter, however, necessarily discountenance speculative papers and discussions. They deal chiefly with accomplished facts, and prefer descriptions of executed work, rather than accounts of new experiments and imaginings of what they may lead to, and yet the latter is precisely the class of papers, which I believe, under proper safeguards, this association should encourage.

The busy men who are developing this country need something more than an account of accomplished successes. They need to keep up with new discoveries and progress even before they are reduced to practical account, and to look into the future as well as in the past; and they especially need that personal contact, which nothing can replace, with men of science, to learn of what is being done and hoped for, and to make known what new information is needed to remove obstacles to their own progress.

Engineers particularly owe it to themselves, not only to come to these meetings for such information as they may lack in the kindred sciences, but to make the other members acquainted with whatever new facts or ideas they may have acquired outside of the routine of their profession. This they can better do in this section than in their various technical societies. Here they can indulge in pure science without regard to the practical use or bearing of the facts which they have discovered, and, provided always that they stick accurately to the facts, the resulting discussion cannot fail in being of value to them as well as to the listeners.

I thus believe that the true field for this section is not only to bring together the men of science and the observers, but also the practical men of affairs; and for this purpose to invite papers perhaps a little aside of those now contributed to the various technical

societies, — papers which, while strictly sticking to ascertained facts, may yet indulge in some speculation as to their eventual results, may lead thought into untravelled paths, and perhaps bring about that the imagining of to-day shall become the accomplished fact of to-morrow.

Especially would I promote the presentation of papers giving an account of experiments which have resulted in failures, or in doubtful successes. Failures are far more instructive than successes; and practical men, when they wish to solve a new problem, first enquire into the failures which have occurred in similar attempts. This is the true scientific method, and yet, somehow or other, many people do not like to present papers relating to their failures. I hold this to be the mark of a narrow mind, and I hope that in the future we shall have many papers upon trials and experiments of doubtful or no success, in order that the chances of others going astray may at least be reduced by one, or that some other member may suggest a remedy.

To promote the presentation of papers, I suggest that some of the friends of the advancement of science, who have the means to spare, shall establish endowments, to offer yearly medals or prizes for the best paper read in this section upon some particular branch of science, or shall offer a special premium for the best essay upon any subject which they may consider obscure. Such prizes or premiums should be designated by the name of the donor, as is usual, in such cases, and should be awarded by a committee, the selection of which is to be designated in the gift. I hope that this excellent practice will be inaugurated before the next meeting.

I hope also that the practice shall shortly grow up in these meetings of the propounding of queries by various members upon subjects concerning which they want to be better informed, or which they deem of general interest. These should preferably be made in a written communication to the secretary of the section. They may be made at any time during the year, and either presented at the meeting, or, if of sufficient importance and not already answered in text books or publications, issued as one of the subjects upon which papers are invited from members. Discussions started in this way are apt to prove most valuable, because they generally relate to some live subject, about which somebody wants to be informed, and the original query becomes the nest-egg around which cluster many interesting observations and facts.

I also suggest that in future the sectional committee or the standing committee shall annually publish a list of subjects upon which papers are invited from present or prospective members, so as to indicate to them the direction in which information and research are thought to be needed. The task of soliciting papers is now left to the chairman and secretary of this section, and when as in the present instance, they are both busily engaged in other duties, they feel that they are not doing the association full justice, for want of time to devote to the necessary soliciting and correspondence.

The circular for Section D, this year, indicated the following classes of subjects, for papers:

Mechanical Science in the abstract, including theoretical and applied mechanics.

Mechanical Research.—The collection of data from experiment or observation, the systematic classification of such data, and scientific deductions from them.

Problems in Engineering of national importance, and such as are connected with more than one branch of engineering, and therefore might properly be discussed before more than one of the American engineering societies.

The Education of Engineers.—"The Best Method of Teaching Mechanical Engineers" was the subject of vigorous discussion at both the Philadelphia and Ann Arbor meetings. The subject must necessarily be enlarged into that of the teaching of all branches of engineering.

The Relation of the Government to Engineers in Civil Life.—What is to be that relation in the future, when the government will require in its public works engineering knowledge and experience beyond what is likely to be found in its military and naval service.

The Endowment and Organization of Mechanical Research.—The work of Regnault must be continued till the steam engine gives up more of its secrets; that of Fairbairn and Hodgkinson must be repeated with modern materials; testing machines like that at Watertown must be made to do the work for the benefit of science, of which they are capable. How is this work to be done? Who is to pay for it?

It would be desirable, however, to divide this up into more specific subjects, so as to remove the vagueness which is unavoidable in their designation by classes; and in order to indicate how large

an additional scope can really be covered, provided the rules requiring abstracts of papers to be furnished in advance be rigidly adhered to, and these abstracts be carefully examined to make sure that no absolutely unsound propositions shall receive the sanction implied by a hearing before this association, I may mention a number of other subjects.

I have already alluded to some inventions as being "in the air." Things, the pressing need of which are realized by many persons, and which many ingenious men are trying to compass. I believe that under proper restrictions this association might fairly invite papers upon them, which shall describe the state of their development, the difficulties which are thought to be in the way of success, and any new facts or observations which have a bearing on the subject.

It may be interesting to mention a few of them. Not in a spirit of prophecy, nor in the attempt to look farther into the future than others, but as inventions which the civilized world is more or less soberly expecting, and which many inventors are now endeavoring to work out.

And first, although it is not yet "in the air," let me mention the possibilities of aërial navigation, inasmuch as I have noticed that whenever an imaginative writer pretends to give an account of future mechanical achievements, or a newspaper antedates an edition a century or so, the first thing which is described is always a flying machine.

The difficulties in the way of success are very great, principal of which is the want of a motive power which shall, with its fuel, be sufficiently light in proportion to its energy, yet there are many sober men who expect eventual success, and in spite of the many failures that have occurred during the last three hundred years, in attempts to solve the problem, there are special societies in England and France to promote investigation and experiment.

You will at this meeting probably listen to a paper by a gentleman who having devoted five years of his life solely to the watching the flight of birds, is convinced that it is accomplished with an expenditure of muscular power far less than hitherto supposed.

However this may be, the world is also expecting the invention of a new motive power. As an evidence of this we may contrast the distrust exhibited of inventors a century ago, with the kind and

credulous way in which the Keely motor has been treated, in spite of the mysterious and thoroughly unscientific methods with which it has been presented.

In spite of the recent glowing newspaper accounts of the success of this so-called motor, I may say, that having some years ago witnessed some of the experiments with it (all of which by the way I then thought could be duplicated by well-known devices) I have no faith in its eventual economical success, and that I look rather to some improvements in gas or petroleum engines to furnish a new power, which shall be more convenient and economical than steam.

Should this be accomplished (and there are many inventors now working upon the problem) the application will be immediate and important, especially for all those machines which must be portable in order to perform their service, such as those for the cultivation and gathering of farm crops, the grading of roads and railroads; the drilling and sinking of wells, etc.

Attempts to introduce steam power upon the farm have hitherto met with but little adoption, in this the chief agricultural country in the world. The steam plow, the steam cultivator, and the steam reaping machine do not yet exist. I believe papers descriptive of what has been attempted would prove of great value, and might enable us to judge whether the want of success is due to inherent defects in the machines hitherto tried, or whether, as I believe more probable, to the practical difficulties in supplying water to a portable machine, which would at once be removed by the perfecting of some motor employing the expansion of some other gas than that of water.

A scientific investigation of the "state of the art," which I hope to see embodied in a paper for this association, may show that there is needed but one single step, to make a complete success of such machines.

The allusion to farm machinery suggests that we also want to know something as to what is being accomplished towards perfecting a machine for picking cotton. Such an invention has been sought for many years past, and quite a number of patents have been taken out. I have seen newspaper accounts of the reported success of a recent machine, but I do not know how accurate these reports are. It is stated that it costs about forty millions of dol-

lars to gather the cotton crop of the United States, and that nearly one-half of this could be saved by an efficient cotton picker, so that the reward of the successful man promises to be very great.

Another invention which may be mentioned, as now in process of evolution, is an electric motor for street traffic. There are in this country and in Europe, scores of inventors at work to solve the practical difficulties of the problem, and there are good grounds for believing that success is not far distant.

As the various systems proposed have been fully explained, and experiments with them have been public, there would seem to be involved no great labor, for some member competent to the subject, in gathering the information and giving this section a paper thereon.

I may also mention the subject of the transmission of power long distances by electricity. Scientific men all over the world have been trying experiments with this in view, and a paper describing the results would be extremely interesting.

In connection with this same subject, I may allude to improvements which are to be expected presently in electric lighting. We know that theoretically the various machines produce the electric light at a cost of only two per cent that of gas, for an equal intensity of light, but that practically, electric lighting is nearly as expensive as gas. This is said to result from the difficulty in sufficiently dividing the electric current, so as to give without waste just the amount of light needed at a particular point. Thus, for instance, it is said that with an arc light of say 2000 candle power, illuminating a railway station, we waste four-fifths of the light, and only utilize one-fifth. This probably can be remedied by a new burner, yet to be invented, which shall furnish a steady arc light of less intensity than is now found necessary to secure steadiness.

I have reason to believe that many experimenters are now seeking the solution of this problem, and I much desire that some of the experiments which have failed shall be described in one or more papers to be read before this section.

Some of you at least are familiar with what is being done towards cheapening the production of iron and steel, by attempts to improve the present processes, or to make it direct from the ore. I hope that at some of our future meetings, we may have papers describing what has been done, and stating what it is theoretically possible to accomplish.

I might go on a good deal longer in the same direction, and endeavor to interest you in speculations as to how science may be advanced by inviting and contributing papers upon this class of subjects; as, for instance, the improvements in mechanical appliances for the sanitation of dwellings; the methods by which meats and vegetables are preserved for food, so as to bear storage and transportation; or upon the new order of architecture which is evidently evolving from the use of iron in buildings; or to several halting inventions which will readily occur to you and which, perhaps, need only such a stimulus to draw renewed experiment to them, such as the type-setting and distributing machine, which was thought to be finally perfected ten years ago, but which has not yet come into use; or the obtaining of sun pictures in colors, an extension of photography which the late Professor Morse told me thirty-eight years ago was almost perfected, and could not fail to become a success.

But I remember that I promised to be brief, and I think I have said enough to indicate how large a scope in my judgment may be covered by this Section of Mechanical Science and Engineering, and how its meetings in the future may be made still more interesting and useful than they have been in the past.

PAPERS READ.

ON THE STRENGTH AND PROPORTIONS OF TOOTHED WHEELS. By Prof. WM. HARKNESS, U. S. N. Observatory, Washington, D. C.

[ABSTRACT.]

THIS paper was presented in compliance with a request from the officers of Section D, and consisted of selections from a long essay in which all formulæ for the strength of gearing, known to the author, were reviewed and the discordances which they exhibit pointed out, after which formulæ were presented which are believed to give trustworthy results.

These formulæ are as follows:

For wheels with cast-iron teeth

$$H = \frac{0.910}{\sqrt{(1 + 0.65v)}} vpf$$

For brass or bronze teeth

$$S = 800\,pf \text{ to } 400\,pf$$

For wood and iron teeth

$$H = \frac{0.455}{\sqrt{(1 + 0.125v)}} vpf$$

In which

H = horse power (550 foot pounds per second).
S = stress in pounds at the pitch line.
v = velocity of pitch line in feet per second.
p = pitch in inches.
f = breadth of face in inches.

The paper will soon be published in full.

MAXIMUM STRESSES ON BRIDGE INCLINES. By Prof. J. BURKITT WEBB, Hoboken, N. J.

[ABSTRACT.]

BY a new system of notation, the formulæ in this subject can be simplified and generalized. In this system all trusses are considered as made up of certain elements, composed each of a chord bay and an incline, and these elements are numbered consecutively from O up to N. A system of accents enables distinction to be made between the different parts and

points of an element. Some new terms belong to this notation, as "maximum point," "maximum segment," "chord segment," etc.

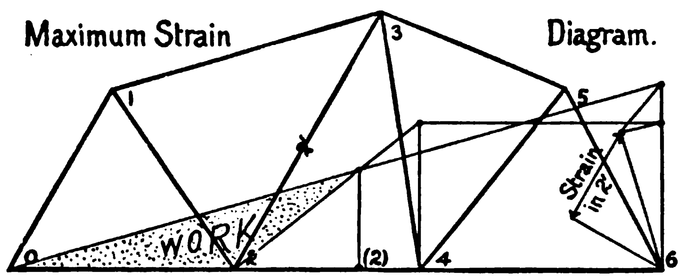
A maximum point is that point of a chord bay from which a load may be hung without producing any stress upon the incline belonging to the same element; or, otherwise stated, the incline of the same number.

A maximum point possesses some other properties which enable it to be found in a variety of ways. Thus, for parallel chords, it divides the chord bay in the same ratio as it divides the span, etc.

These properties lead to simple graphical determinations for parallel chords.

For any regular truss these principles may be applied analytically and very simple formula obtained for the maximum stresses on inclines.

Irregular trusses may be discussed in a very simple manner graphically, the following diagram showing the work required to find one, (2), of the



maximum points. If a uniform load be run up to a maximum point, the maximum stress is obtained and the simplest method of doing this is to divide the work done by the load, when 2 descends a differential distance, by the resulting strain in the second incline, etc. The maximum points are here found on the principle that if 2′ be removed and the truss distorted (2) will remain in the same right line with the abutments. This principle applies also to a load varying according to any law, and also to a system of concentrated loads at fixed distances apart; in both these cases the position of the end of the load is not determined directly by the maximum point, but may be generally stated thus: the maximum in 2′ occurs when the load between 0 and 2 is to that between 2 and 4 as 02 is to 2(2), there being no load beyond 4, and the same for other joints. The values of the stresses can be found by virtual moments, or the principle of work, as above. It may also be stated that, considering the distortion produced as above described, and the load running down hill from 0 to 2 and then up toward 4, the maximum in 2′ occurs when the centre of gravity of the load reaches the lowest point.

ON THE FRICTION OF THE STEAM ENGINE. By Prof. R. H. THURSTON, Ithaca, N. Y.

[ABSTRACT.]

IT has been generally assumed, among engineers conversant with the operation of the steam engine, that the total resistance of the engine is made up of two principal parts, the one that due to the load, the other that produced by the friction of the engine itself. Of these two quantities, the one is a simple factor of the power produced for the purpose of doing useful work, and is proportional to the amount of that work; while the other has been usually supposed to be composed of two parts, the constant resistance of the engine, *per se*, and the other the increased resistance of the engine produced by the pressures thrown upon the machine by the imposed load. The whole resistance has thus been assumed by De Pambour and his successors to be represented by the formula

$$R = (1 + f)\, R_1 + R_0, \tag{1}$$

in which R is the total resistance met with at the piston, R_0, the resistance of engine unloaded, and R_1 that due to the load, fR_1 being the increase of engine friction due to the action of the load. The value of f is taken by De Pambour at 0.14 and by Mon. Lhoest at 0.10.

Professor Rankine proposed a simpler expression,

$$R = (1 - f) R_0, \tag{2}$$

in which f is given as 0.2 or 0.25, which he thinks may be taken as approximately correct for ordinary purposes.

The writer has long been desirous of ascertaining whether the De Pambour formula can be safely taken as correct for steam engines generally, and whether it is accurate for the more modern forms of engine especially. An opportunity was offered, in the winter of 1883–4, through the kindness of Prof. John E. Sweet, one of whose engines was on exhibition at the exhibition of the American Institute at that time. The investigation was made, under the supervision of the writer, by Messrs. Aldrich and Mitchell, then of the Stevens Institute of Technology, who applied indicators and a Prony brake, comparing the amount of power thus measured at the piston and at the brake, ascertaining the difference, and determining it as a function of total power for a wide range of work, extending from that required to drive the unloaded engine up to considerably more than the rated working power of the machine. The work was very carefully and skilfully done, but the results have remained unpublished up to the present time. It was the desire of the writer to see the experiments repeated upon another engine and thus corroborated, should the law revealed by the first investigation be a general one. An opportunity to secure this confirmation of the earlier work was presented recently, in the course of work done in Sibley College, Cornell University, the investigation being made by Messrs. Day and Riley, of the class of 1886. Their records, which now lie before the writer, fully confirm the conclusions reached by him two years earlier from an examination of the records of the work done at the exhibition of the American Institute.

It is the intention of the writer to take an early opportunity to publish the details of these experiments and to present at considerable length the conclusions derived from them. But it is proposed to give here the principal results which are apparently indisputable, and thus to open a discussion and to stimulate further researches in this direction.

Stated in brief, it may be said that the friction of engine was found to be practically constant at constant speed, whatever the work done and resistance overcome by the engine exterior to itself. In other words, the addition of external load had no important effect upon the magnitude of the frictional resistance of the engine itself. In De Pambour's formula, the value of f thus becomes actually, or approximately, zero. The frictional resistance being independent of the resistance due the load, the formula given by Rankine, for this class of engine,—the high-speed "automatic" engine—is thus seen to be inadmissible.

The friction being a sensibly constant resistance, the pressure per square inch of piston required to drive the engine itself is thus also constant at constant speed, regardless of the total power exerted, and the additional pressure demanded is directly proportional to the power expended exterior to the machine and to the external resistance. The admissible formula is thus seen to be

$$R = R + R_0. \tag{3}$$

The experiments with both engines gave this friction-pressure as at from three to five pounds per square inch of piston, for these small engines, the power of which ranged only up to about 40 I. H. P., as a maximum. As is well known, it is much less in larger engines. It was further found that the friction of engine increases with increasing speeds of engine and with increasing steam-pressure. The former was a result anticipated as a matter of course; but the latter was quite unexpected, as the writer had long since found that the coëfficient of friction of well-lubricated surfaces decreases, throughout the range of common practice in the steam engine, with increase of pressure, and his conclusion has been since confirmed by many later investigators. As will be shown in the unfinished paper of which this is an abstract, this apparently singular and abnormal fact is probably due to the variation in the distribution of steam which occurs in the engine with automatically adjustable expansion, when the load and speed are constant and steam pressure varies.

These facts have seemed to the writer so interesting that he has been unwilling to delay their publication until the full account of the work could be prepared, or to defer its announcement to the Association until the meeting of another year.

RIVER AND HARBOR IMPROVEMENTS, WITH SPECIAL REFERENCE TO THE IMPROVEMENT OF THE NEW YORK ENTRANCE NEAR SANDY HOOK. By Prof. LEWIS M. HAUPT, University of Penn., Philadelphia, Pa.

[ABSTRACT.]

THE subject was introduced by remarks upon the importance of cheap transportation, and the great national benefits to be derived from the im-

provement of the water-ways of the country. The effect on railroads was stated to be beneficial instead of injurious. Then followed a statement of the general principles and requirements of this class of problems, in which the author maintained that all structures of any considerable magnitude and weight, intended to regulate currents, and which rested on, or depended upon sandy or alluvial bottoms for their support, violated to a greater or less extent the fundamental requirements that they shou'd not oppose the ingress of the tide, nor injuriously modify the currents, also that dikes or jetties were to a great extent below the zero plane or plane of action of waves of translation, and were dependent for their strength upon their mass, and that this was frequently composed of individual fragments of small dimensions, not cemented. It was stated that all such constructions occupy a large volume, produce great pressure and leverage — are wasteful of time and materials, result in serious modification in the regimen of rivers or harbors, are unnecessarily expensive, and if improperly located, they cannot be readily changed. In strong contrast with this, the author then suggested a solution, consisting of a floating system of deflectors intended to be attached to buoys or floats, and anchored to heavy moorings, composed of ground chains, held in place by screw discs sunk considerably below the bottom.

This system being held up by the buoys, is to be guyed in place on the ebb side by wire cables or chains, and is made to depend for its efficiency upon the tensile strength of wrought iron.

It is composed of units or parts readily assembled, which occupy little space, admit the tides readily, yet control the currents and deflect them upon the obstruction to be removed. It is comparatively inexpensive, and can be quickly erected and removed. By it the prism of water passing through a given section can be increased almost indefinitely, while the aperture of discharge may be diminished, thus producing any required velocity, etc.

The physical conditions of the problem at Gedney's Channel were stated, attention called to the existence of a peculiar deep basin on the bar, and the method of utilizing the resultant which maintains it for the improvement of the channel. Various other plans proposed for this harbor were briefly noted and commented upon, and a résumé given of some of the efforts to apply surface velocities for removing bars with the reasons for their failure.

Stress was laid upon the importance of applying a method which should be limited to the removal of so much of the crest of the bar as would secure the requisite channel and no more, as any excessive disturbance of the bar would result in uncertainty and injury to the existing channels, and would, of necessity, be much more expensive. The system which Prof. Haupt suggested and advocated, is intended to depress the plane of tidal scour upon the bottom, while it increases locally the volume of the stream; removes sufficient material to give a clear channel at thirty or more feet depth, and maintains it against the forces of the flood, at a minimum of time and cost.

SOME DIFFICULTIES TO BE OVERCOME IN MAKING THE PANAMA CANAL. By Dr. WOLFRED D. E. NELSON, New York, N. Y.

[ABSTRACT.]

THE paper briefly refers to the *major* difficulties to be encountered in canal building on the Isthmus of Panama. They are as follows:— The swamps and quicksands at Mindi,—Atlantic Section. The dam at Gamboa to divert the Chagres into its new channel. The vast cut at Culebra. The tidal-basin at Rio Grande,— Pacific Section. The climate of the Isthmus, and a few general considerations.

THE COMMITTEE OF THE SECTION ON THE USE OF ACCURATE STANDARDS IN THE MACHINE-SHOP.

THE committee did not make a formal report, but its chairman Prof. W. A. Rogers presented a paper on the use of the microscope in the machine-shop, as an introduction to the discussion which followed. The committee was discharged at its own request.

ON THE USE OF THE MICROSCOPE IN THE MACHINE-SHOP. By Prof. WM. A. ROGERS, Cambridge, Mass.

[ABSTRACT.]

AFTER a general statement of the difficulty of doing accurate work in the machine-shop by the present methods the author pointed out the different ways in which the microscope may be usefully and economically applied in ordinary machine-shop practice.

THE COMMITTEE OF THE SECTION ON THE BEST METHODS OF TEACHING MECHANICAL ENGINEERING.

THE committee reports that papers bearing upon the general subject had been prepared by Dr. Thurston and Professor Alden, who were present and would read them before the section. The committee was then, at its own request, discharged.

THE RELATIONS OF MANUAL PROCESSES TO PRIMARY AND HIGHER EDUCATION. By Prof. GEO. I. ALDEN, Worcester, Mass.

[ABSTRACT.]

A DISCUSSION of the use of manual processes in education leads the author to enunciate four general principles which should be observed, as follows:

The first principle for the regulation of manual processes as a part of a system of education is:

Manual processes in education must be primarily for the acquirement of knowledge and discipline.

The second is:

Manual processes in education should be such as are adapted to the development of powers, faculties, and habits of mind which have been but little cultivated in the schools.

The third is:

Manual exercises in education should be restricted to those operations for which suitable facilities are provided for carrying them out in a thorough and practical manner; or, in another form: Correct methods of manipulation are essential to the best results both in knowledge and skill.

The fourth and final principle is:

Manual processes involving the use of tools and construction should be confined to properly designed structures; should be taught and supervised by experts capable of producing the best quality of standard practical work, and should be accompanied by competent instruction in theory and principle.

PROPOSAL FOR AN AMERICAN ACADEMY OF ENGINEERING. By WM. KENT, Jersey City, N. J.

[ABSTRACT.]

THE writer proposes an Academy of Engineering composed of army, navy, civil, mining, mechanical, sanitary, and electrical engineers, selected out of members of not less than five years standing in the existing societies. The object of the Academy will be to bring into closer relations the members of the various branches of the engineering profession, to found a library, and an engineering laboratory, to conduct researches in questions relating to the public health and safety, and to be the custodian of funds to be held in trust for the prosecution of research. The paper describes at length the need for such an academy, and a scheme for its organization as follows:

The original members of the Academy to be the presidents and past presidents of all the engineering societies of the United States. These men to meet to incorporate the Academy. After its nucleus is thus formed it is to grow by accretions of members from the American societies as follows:

Five members to be chosen each year from each of the large societies, the civil, mining, and mechanical engineers, and two each from the army engineers, the navy engineers, the sanitary engineers and the electrical engineers. The following is the method of election proposed.

Each active member of each of the societies named chooses from the whole list of members of his own society of not less than five years standing a number of names equal to the number to be elected from his society, which he writes upon a ballot. Tellers select from all the names voted, those having the highest number of votes, the ten highest from each of the large societies, and the four highest from each of the others. The names thus selected are printed upon a ballot, and the members of the

Academy vote upon them by striking out one-half of those nominated by each society. The ballots thus scratched are counted by tellers, who certify as elected those receiving the highest number of votes; five out of the ten nominated by each of the larger societies, and two out of the four nominated by the others. Members elected to the Academy thus have to pass through two ordeals: first, they must be among those receiving the highest number of votes in their own society for the nomination, and second, they must be among those receiving the highest number of votes of members of the Academy.

A DEDUCTION FROM THE EQUATION OF "THE MOMENT OF THE MOMENTUM" IN THE CASE OF TURBINES. By Prof. DE VOLSON WOOD, Boonton, N. J.

[ABSTRACT.]

THE general equation is

$$Mt = \Big[\delta Q \, (v \cos \varphi - \omega \rho) \, \rho \Big]_{\text{limit (initial)}}^{\text{limit (general)}}$$

In which

ω = the uniform angular velocity.
v = the velocity of the water relative to the bucket.
ρ = the radius vector to any point of the bucket.
φ = the angle between the normal to the bucket and the radius ρ.
δ = the density of the water.
θ = angle between two radii.
Q = the quantity of water flowing past the arc $\rho\,\theta$ per second.

Also let x = the depth of the water passage at the end of ρ,

$m = \delta \, x \, \rho \, d\theta \, d\rho$ = mass of elementary prism

$$\delta Q = \text{[illegible]} \; V \sin \varphi = \frac{m}{d\theta \, d\rho} \theta \, v \sin \varphi.$$

Differentiating twice, I find

$$d^2 M = \rho \sin \varphi \left(- 2 m v \omega + m v^2 \frac{\cos \phi}{\rho} - m v \sin \varphi \frac{d\phi}{d\rho} + m v \cos \varphi \frac{dr}{d\rho} \right)$$

which is to be interpreted.

A CONTRIBUTION TO THE THEORY OF THE MAXIMUM STRESSES IN BRIDGES UNDER CONCENTRATED LOADS. By Prof. H. T. EDDY, Cincinnati, Ohio.

[ABSTRACT.]

A description was given by the author of some of the features of a work which he is preparing for publication, which is to include a number of theorems for determining the maximum stresses in bridges due to the wheel concentrations of a railroad train, applied by convenient and novel methods to simple girders, single and double intersection trusses and drawbridges.

AN IMPROVED FORM OF CHIMNEY-DRAUGHT-GAUGE. By Prof. OLIN H. LANDRETH, Vanderbilt University, Nashville, Tenn.

THE instrument described was used in a series of evaporative coal tests conducted at the Vanderbilt University Engineering Department, during 1885.

It was designed to supply the want of precision of the simpler forms of draught-gauge, and accomplishes it by using an inverted siphon-gauge with water as the fluid, with the plane of the legs of the siphon inclined at an inclination of *one in vertical* to *five in length of slope*, thus magnifying the quantity to be observed; and further by reversing the long and short column, it eliminates the effect of errors of *inequality* of *capillarity* and *inequality* of *level* of the corresponding graduations on the scale to both of which the common form is also subject. This reversal is accomplished by having *each leg* connected with the chimney flue through a three-way stop-cock one of which is always kept opened for the flue, at the same time the other is opened to the air. This reversal also insures interior wetting of tube and more perfect capillarity, and does not materially increase the labor of reading the scale as its graduations are numbered with but *one-half* their true value, so that the *sum* of two readings gives at once their *arithmetical mean*. The inclination of the tube moreover gives an elliptic or nearly a pointed meniscus which gives a more precise bisection or pointing on the scale, than the usual circular meniscus in the vertical tube.

THE SOARING BIRD. By ISRAEL LANCASTER, Chicago, Ill.

A METHOD OF HEATING VERTICAL FLUE BOILERS BY NATURAL GAS. By J. A. BRASHEAR, Pittsburg, Pa.

AN EXAMPLE OF CYLINDER CONDENSATION AT DIFFERENT SPEEDS. By Prof. DE VOLSON WOOD, Hoboken, N. J.

A METHOD OF ESTABLISHING A MONUMENT POINT HIDDEN BY AN OBSTACLE FROM THE TRANSIT STATION. By STEPHEN S. HAIGHT, New York, N. Y.

ON THE EDUCATION OF ENGINEERS AND ON THE DEGREES CONFERRED BY SCHOOLS OF ENGINEERING. By Prof. R. H. THURSTON, Ithaca, N. Y.

THE GREAT BRUSH DYNAMOS OF THE COWLES CO. By Prof. R. H. THURSTON, Ithaca, N. Y.

SECTION E.

GEOLOGY AND GEOGRAPHY.

ADDRESS

BY

T. C. CHAMBERLIN,

VICE PRESIDENT SECTION E.

AN INVENTORY OF OUR GLACIAL DRIFT.

It is the custom of men of affairs to pause at times in the course of their occupation and take account of stock on hand, of business done and of the prospects that lie before them. As merchants, they list their goods and note their changed values. As manufacturers, they take inventory of finished products, of partially manufactured stock and of crude material on hand. As miners, they estimate the ore in sight, scrutinize past developments and forecast the future. So it may befit us, as miners, and, in a sense, manufacturers of systematic truth, to inventory our products and prospects, to schedule our supposed final results, our half-manufactured stock and our crude material, and glance forward at the amplitude of undeveloped resources.

To inventory our wealth, even of recent acquisition, in the broad field of geography and geology in the limits appropriate to this sketch, is quite impossible. Our recent geographical gains have been among the most important in our history; not indeed so much in the field of new discoveries of physical features as in the higher field of precise knowledge. The great governmental surveys have made large advances in replacing imperfect and inexact geography by that of a much higher order of precision.

Nor is it possible to count our gains in all parts of the geological column, from the "fundamental gneiss" to the latest furrows of the ploughshare, the dominant geological agency of to-day. Great have been the activities throughout. From base to summit, the series has been scrutinized with unusual zeal, and the most fruitful results have been attained. But limitations of time and limitations

of knowledge alike restrict my attempted inventory to the narrow field of the glacial products of the Quaternary age. But even here the wealth of fact is so large that no account of the sources can be taken and little individual honor done its producers. It will be impossible to fitly designate the scientific firm or factory from which each scheduled product has been put forth, whether it issued from individual, state or national workshop. To the connoisseur the goods will be known without the maker's label. With the public, let the merit be ascribed to the host of diligent workers of the last half century whose results are inseparably merged in the possessions of to-day.

I crave still further indulgence. So indefinitely linked are recent with earlier acquisitions that I shall make no attempt at separation. An inventory rather than a review of progress will be attempted.

We are now in possession of an approximately accurate mapping of the southern limit of the great glacial formations of North America. Details remain to be worked out, but the great facts are now before us. The eastern portion of this limit is already well known; its supposed coincidence with the southern borders of New England, its northward arch across New Jersey, its northwesterly course across Pennsylvania, its angle in western New York, its southwesterly trend into Ohio, with a southerly loop to the borders of Kentucky, its sweep northward into the heart of Indiana, its extreme southern loop in Illinois, reaching the latitude of 38°, its approximate coincidence with the Mississippi river to the mouth of the Missouri river, its close proximity to that river until it enters Kansas, whence its course is onward for about one hundred miles, where it curves northward, and stretching across Nebraska, joins the Missouri river in southern Dakota. Thence it meanders near that river to the latitude of Bismarck, where it turns abruptly to the westward and passing into Montana, crosses the Yellowstone river a little below Glendive. Passing north of the Judith mountains, it again touches the Missouri in western Montana near the mouth of the Judith river, but at once swings away to the southward, to again strike and cross the river forty miles above Fort Benton and about the same distance from the Rocky mountains. Thence it curves rapidly to the northward, crossing the national boundary at the very foot hills, and thence skirts them northward to the limits of present determination. This is

the outline of the great northeastern sheet of drift. Along the Rocky mountains, within the United States, it barely comes in contact with demonstrable glacial formations from the adjacent mountains, though widely intermingled with mountain "wash." To the westward in the valleys of Flathead, Pend D'Oreille and Osoyoos lakes and of Puget sound are massive deposits of drift partly of northern and partly of local mountainous derivation. The Pend d'Oreille and Puget sound deposits appear unquestionably to be tongues of the drift of British Columbia, which, if not constituting a continuous mantle, at least passes beyond the character of simple local mountain drift.

Southward of these great accumulations there appear deposits of ancient glaciers along the Cascades, the Sierras, the Rockies, and some of the intermediate ranges, and, at least, according to several authorities, along the Appalachians.

To be associated with these glacial deposits because of their probable coincidence in time and connection in causation, are the extensive lacustrine accumulations of ancient Bonneville, Lahontan and a host of smaller extinct lakes of the great basin area.

North of the sinuous margin above sketched, over the whole territory of the United States, save that of the remarkable driftless area of the upper Mississippi, and over so much as is known of the vast Dominion of Canada, east of the mountains, there is spread by far the greatest mantle of glacial débris yet recognized upon our globe, whether in Arctic or in more temperate latitudes. Over this vast expanse, a sheet of ice-ground débris is spread upon an ice-scored floor. Of this I beg to speak as a glacier-formed product, not to the exclusion, however, of other agencies as concurrent factors of importance in the history of the Ice Age. Among the results of recent investigations I would reckon the completion of the demonstration of the general truth of the great doctrine of Agassiz respecting the glacial occupancy of the greater portion of this vast tract.

A wealth of significance lies in the sinuosities, vertical undulations and varying characters of the southern border. It undulates over the face of the land in great disregard, though not in total negligence, of topographic relief, ranging from the sea level to 4,000 feet and upwards. Its vertical profile is nearly as undulatory as that of an arbitrary section from New York harbor to Puget Sound. The sinuosity of the margin, advancing in the valleys

and retiring on the highlands, is indeed a topographic effect, but the vertical oscillations remain scarcely the less pronounced. The border line not only is not horizontal, as though it marked the margin of some ancient ice bearing body of water, but it could only be reduced to such horizontality by the most incredible warpings and dislocations of the crust of the earth.

The border of the drift presents three notable phases. In one, it terminates in a thickened belt of ridged drift, a distinctive terminal moraine; in another, it ends in a thin margin, often little more than a fringe of scattered bowlders, while in the third, the edge becomes attenuated in an extreme degree, vanishing in scattered pebbles, progressively growing finer and more distant until they almost imperceptibly cease.

The morainic border prevails in the Atlantic region and lies on or near the limit as far west as central Ohio, beyond which it retires from it. Throughout the rest of the long stretch to the Rocky Mountains, the attenuated drift edges prevail. The difficult discrimination between these attenuated borders, has not everywhere been drawn and requires too much qualification of statement to be attempted here. One probably represents glacial and the other glacio-natant action. But this is yet an open question. The attenuated borders are believed to delimit an earlier ice incursion and the morainic border a later one, which overrode the former in the coast region but fell far behind it in the interior, the morainic border of the east finding its extension in a morainic border in the interior north of the limit, while the attenuated borders which there creep far out beyond it are lo-t beneath the later drift at the east. The two great ice incursions differed markedly in frontage and in the vigor of their action.

Corroborative of the testimony of the border phenomena we have now a great array of facts drawn from differences of orographic attitudes, of drainage, of erosion, of decomposition, of ferrugination, of vegetal accumulations, and of lacustrine oscillation in the Great Basin, which demark with scarcely less than demonstrative force, two great epochs of glacial history.

Respecting the interval between the two, the great erosions of the Missouri, the upper Ohio and the Allegheny Rivers perhaps afford the most appreciable geological measures. The latter may be taken as an illustration. Glacial river deposits of the earlier epoch—if I interpret correctly—form the cappings of fragmentary

terraces that stand 250 to 300 feet above the present river, while other glacial deposits heading on the moraine of the later epoch stretch down through a trough excavated in these earlier deposits and in rock below to some such measure as 250 or 300 feet, making no allowance for possible excavation below the present river, and the greater part of this was in rock. It is the judgment of the hour that in the interval the Allegheny, Monongahela, and Upper Ohio rivers sank their beds at least 200 to 300 feet, and the upper Missouri River to a greater depth.

Both the earlier and later drifts embrace important subdivisions, the full values of which are yet undetermined. Present data seem to indicate at least two important subdivisions of the earlier and several subordinate divisions of the later.

Only a hasty glance can be given to the distribution of these. To avoid positiveness of statement, unfitting conclusions not fully established, let us merely picture to ourselves the attenuated edge of an older sheet of drift emerging from beneath the morainic border of the younger in western Pennsylvania and constituting a mere fringe as far as the center of Ohio, but beyond that point emerging broadly and expanding to great width in the Mississippi valley, occupying a great area in Illinois, Missouri and Nebraska and parts of the adjacent states, again narrowing in Dakota, where it is almost completely overridden by the later sheet, until, in the latitude of Bismarck, it again expands broadly, stretching westward to the Rocky Mountains and northward to an unknown distance in the British Possessions, and we have the picture which we would draw of the exposed portion of the earliest drift sheet, the lower member of the earlier group.

If, again, emerging from beneath the moraine-bordered drift in central Ohio, we picture another drift sheet overlying the former, similar to it in many of its characteristics, and separated from it by beds of assorted material, by old soils, by horizons of ferrugination and by vegetal accumulations, preserved here and there in such frequency as to have received popular and suggestive names, such as "chip yard," "Noah's barn yard," etc., and occupying considerable territory in southwestern Ohio, southeastern and west-central Indiana, central Illinois, central and northeastern Iowa, and eastern Minnesota, forming, taken together, a lobate leaf emerging from beneath the moraines and overlapping the older sheet, we have the conception of the second drift sheet of the ear-

lier epoch. This is but the correlation and interpretation of the hour, subject to correction from the extended investigations which will yet be required to place the differentiation and coördination of these earlier drift sheets upon a thoroughly demonstrative basis.

If, turning to the later series of drifts, we picture a complex group of sheets so intermingled by the forceful action of the ice in their formation as not to be separable with confidence, bordered usually by terminal moraines, and covering the whole of New England and New York, portions of northern New Jersey, Pennsylvania and northern Ohio, northern Indiana, the northeastern corner of Illinois, the whole of Michigan, the major portion of Wisconsin, all but the southeastern and southwestern parts of Minnesota, the north-central part of Iowa, the greater part of Dakota east of the Missouri river and stretching to undetermined limits northward in Canada, we have an outline of the second group of drifts.

If again we picture a series of sheets of less irregularity of material, less uneven distribution of the stony constituents, greater uniformity of thickness, greater smoothness of surface, occupying the great basins of the St. Lawrence valley, the Red River of the North and limited areas of the eastern coast, the whole superposed upon the preceding and separated therefrom usually by stratified material, and delimited in part by definite beach ridges, we have an outline sketch of a third group of drift sheets.

Concerning the first or oldest series, it is the major opinion that they owe their origin to direct glacial action, but this opinion is not unanimous. Some investigators of large familiarity with the facts entertain the conception of a glacio-natant origin.

Concerning the second or moraine-bordered group of formations there is an overwhelming preponderance of opinion that they are direct glacier products, aided only by those aqueous agencies that are the inevitable accompaniment of glacial action.

Concerning the third series, the weight of opinion favors their subaqueous deposition, either in fringing lakes gathered along the borders of the ice in its retreating stages, or in a more general submergence of the land. The products of fringing lakes are essentially demonstrable. So are marine deposits in the coast region and in the Lower St. Lawrence basin, but marine submergence beyond these districts is thus far unsupported by specific evidence. The deposition of this third series was intimately connected with

the decline of the second glaciation and no essential interval of time lapsed between them.

Each of these three groups embrace bowldery clays, and assorted deposits, but differ widely in their special features. The older group bears osars and kames in moderate abundance, but drumlins and marginal moraines are but feebly developed, but, by compensation, the great body of the loess lends to this series its peculiar interest.

Associated with the second group are the most extraordinary terminal moraines known, the most extensive aprons of morainal overwash, the greatest valley streams of glacial gravel springing from morainic heads, the finest variety and widest distribution of drumlins, some of the most remarkable systems of osars, by far the most extraordinary known development of kames and pitted plains, the most scanty association of loess, bowlder trains of the most striking and convincing character and bowlder belts of the finest order, while below on the rock surface are abrasions, groovings, and striations of the greatest variety and of the most phenomenal character.

With the third group are associated beach ridges and shore belts, some of which have been traced and leveled hundreds of miles by the most competent observers, but no true osars, kames, drumlins or moraines.

We have now arrayed our scientific goods in three leading departments; we have placed them on three floors. We may now turn to the inventory by subordinate classes in some negligence of this separation into great departments.

Our unstratified bowldery clays, now styled tills, may be first scheduled. Of these there are the richest variety and the most perplexing gradations. They range from those in which the stony material greatly predominates to those in which it is barely present; from those in which erratics are clustered in the most irregular fashion to those in which their distribution is practically uniform; from those which are the most compact in texture to those which are open, loose, and porous; from those in which the matrix is chiefly clay to those in which it is largely sand, while the erratics themselves present the utmost variety of form, size and constitution. These variations are expressions of the mode of derivation, of the nature of the parent formations, of the drainage conditions, and of the mode of deposition. The permutations and combi-

nations of these cannot be catalogued, but the following genetic classes of tills may be recognized: (1) subglacial tills, (2) englacial or superglacial tills, (3) subaqueous tills, and (4) tills ridged by the thrust of the margin of the ice. The first accumulated beneath the ice sheets, presumably near their terminal borders; the second were derived from material within and upon the ice and let down by its melting; the third were formed in the glacier-bordering waters by the combined agency of ice and water acting in several different phases of co-partnership which cannot here be specifically described; the fourth embrace those tills that were pushed into ridges by the edge of the ice, or, in other words, the till of terminal moraines.

Our stock of moraines is large and well advertised. It may have been swelled a little by a too free use of the label on doubtful articles, but there is a varied and choice assortment of the genuine goods. It embraces terminal, lateral, medial and interlobate moraines — not to include the great ground moraines lest confusion arise. Brief allusion has already been made to the great terminal moraines which overshadow all others in interest and importance. In magnitude and significance they are unapproached by any similar phenomena yet recognized or, possibly, to be recognized on the eastern continent. The grander phases of the phenomena are already before the scientific public. Important details have been added and the demonstration of their morainic character strengthened by specific data, and increased precision. There seems to me more ground than ever before for placing the great moraines of southern New England, northern New Jersey and Pennsylvania in direct correlation with the great moraines of Wisconsin, Minnesota and Dakota. To my view, the moraines which start on Nantucket and on Cape Cod, respectively, after pursuing their sinuous courses across the country, alternately separating and uniting, alternately becoming subdued and growing stronger, reappear in the members of the Kettle Moraine of Wisconsin and again upon the Coteaus of Dakota, as the Altamont and Gary moraines, respectively, and at length, on the plains of British America, as outer and inner belts there, at points distinctly discernible.

Outside of these chief moraines are occasional tracts of the older drift that are aggregated in the similitude of peripheral moraines. Examples are to be found in central Indiana, western Montana, and the plains of the British Possessions.

Back from the two principal terminal moraines there lie partially determined belts, partaking more or less distinctively of the character of terminal accumulations. A few have been recognized in Maine; some in the heart of New England, several in New Jersey, New York and Pennsylvania, a considerable group in Ohio, Indiana and Michigan, three or four in Illinois, as many in Wisconsin, eight or ten in Minnesota, and about an equal number in Dakota, and similar phenomena in Manitoba and north of the great Lakes may be classed here, though they have received a different interpretation at the hands of our Canadian brethren.

Our most unique moraines are the interlobate, developed between the tongues into which the great ice sheet of the second epoch was so remarkably divided at its margin; so unique indeed that some hesitancy in the acceptance of the type has been felt. But a glance at the Minnesota and Dakota lobes will make it evident that a slight growth would force their latero-terminal ridges together into a moraine more gigantic than even their present impressive dimensions. By comparative studies of the whole series of lobes the history of interlobate development is traceable. When the lobes became closely pressed together and shed their waters into the common interlobate valley, drainage phenomena became preponderant and the semi-morainic kames and pitted plains became the dominant phenomena. Some of these were probably developed progressively during the growth and decadence of the contiguous lobes. About a dozen interlobate moraines have been recognized, located in Massachusetts, New York, Ohio, Michigan, Wisconsin, Minnesota and Dakota, but only a part of these present full evidences of true interlobate character. These may be enumerated among the phenomena that are, so far as now known, peculiarly American, though it is not to be presumed that they are entirely without representation in Europe.

Beautiful examples of lateral moraines abound in the mountainous regions of the west. They are perfect in definition and impressive in magnitude. The known forms belong partly to isolated mountain glaciers and partly to localized glaciation supervening upon the retreat of the last great *mer de glace*. Several observers have recognized such phenomena in the mountains of New York and New England.

Medial moraines are the rarest and least significant of the morainal phenomena of our drift, the obvious consequence of the con-

tinental character of the northeastern glaciers. The localized glaciers of the mountains have given us essentially all yet identified and these are unimportant.

Somewhat allied to the true moraines are the special forms of aggregation of the subglacial débris, or — interpretation aside — of the great sheets of till. They present a richness of variety and of intergradation that almost defy classification. The list of, forms embraces (*a*) till tumuli, (*b*) mammillary and lenticular hills, (*c*) elongated parallel ridges trending with the ice movement, (*d*) drift billows akin to the above but without individual symmetry or discernible parallelism of axes or definite arrangement, giving a smoothly undulatory contour to the surface; (*e*) crag and tail; (*f*) precrag and combings; (*g*) veneered hills, and a great residual congeries of irregular embossments and unclassifiable till hills. The most remarkable are the mammillary, lenticular and elongated ridges, now frequently included under the term drumlins, which have become subjects of special inquiry. These have a fine development in southern New Hampshire, central and eastern Massachusetts, northeastern Connecticut and Nova Scotia, in all of which the elliptical or lenticular varieties prevail. They have a still more remarkable development in central New York, where the elongated type predominates. They have an even more varied development in eastern Wisconsin, extending into the northern peninsula of Michigan, where all varieties, from till tumuli to the extremely elongated ridges, are abundantly developed, the number of individuals being probably not less than 5,000. About 1,000 drumlins have been mapped in New Hampshire, about 1,200 in Wisconsin and large numbers in Massachusetts and New York. The total number within areas already known probably aggregates 10,000. These are almost wholly confined to the area of later drift.

No theory of their formation has yet received wide acceptance, beyond a general agreement that they are subglacial phenomena. Their precise genesis is one of the riddles over which we are still puzzling.

Turning from the tills to the assorted drift, two classes that have commonly been embraced among the glacial formations will be here set aside. First, certain preglacial gravels, sands, and silts believed to have been reckoned with the glacial products through erroneous identification. Of this class the great example is the extensive sand and gravel deposits of the Mississippi and

its tributaries widely known as the "orange sands" and accepted as Champlain deposits. It is too early to speak of the whole of these, but the great mass do not appear to possess the distinctive characteristics of glacial gravels but are residuary in aspect, and at present I do not feel at liberty to embrace them among our glacial formations. It at least seems to me clearly true from other evidence that their reference to the Champlain epoch is as far as possible erroneous, within the limits of the Quaternary age. If they belong to the glacial period at all, it must be to its earliest stage.

The second class to be set aside from the stricter glacial class, are those which have been reworked and redeposited by wholly non-glacial agencies since the drift period. They are glacial only in the sense of being derivatives from glacial formations, but their immediate genesis is wholly non-glacial. This is modified or secondary drift, but not strictly glacial drift.

Eliminating these, there remain the products of glacial waters working contemporaneously and coördinately with the ice. Of these, we recognize two important classes: (1) those which gathered immediately within and beneath the ice-body itself, or against its margin, and (2) those which were borne to distances beyond its limit by the glacial drainage or by peripheral waters. In the first, the presence and restraint of the ice was an essential factor, in the second, it was only a source of water, ice and débris. Of the first class, there are (1) the products of streams flowing on the surface of the *mer de glace*, (2) the products of streams plunging from the surface to the base through crevasses, (3) the products of subglacial streams in tunnels beneath the ice, (4) the products of streams in ice cañons at the glacial border, and (5) the *debouchure* deposits of streams at the margin of the ice. They constitute gravel heapings at once singular in their forms, positions, and internal structure. In none of these are they like the gravel deposits of familiar agencies. They embrace a great variety of sub-types, including isolated tumulous mounds, conical peaks, clustered hummocks with enclosed pits and basins, and sharp steep-sided ridges, sometimes short, and sometimes of phenomenal length. They are distributed in great independence, but not in entire neglect of topography and natural drainage. They possess great inequalities of material and their stratification is usually curved, irregular and discordant and often disturbed, while their external slopes are fre-

quently as steep as the material will lie. In eastern New England, especially in Maine, and in New Brunswick, there is a phenomenal development of elongated, winding gravel ridges, trending in the general direction of ice movement, reaching lengths — neglecting short, though frequent interruptions — occasionally exceeding 100 miles and attaining heights of 140 feet — identical in all essential respects with the great osars of Sweden. Less remarkable examples occur widely distributed over the area of newer drift, and less frequently over the older.

Throughout the rest of New England and New York, the northern portions of New Jersey, Pennsylvania, Ohio and Indiana, the greater part of Michigan, northern Illinois, eastern and northern Wisconsin, northern Minnesota, north central Iowa, eastern Dakota and many portions of Canada, there are innumerable examples of gravelly hummocks, isolated and clustered, constituting the ill-defined class to which the term "kames" is now so commonly applied.

These osars and kames are among the most fascinating phenomena of the drift and have drawn to themselves much attention; but to differentiate them and determine to what extent they are superglacial, subglacial or debouchure phenomena is a triumph of discrimination not yet attained. It is of most practical importance to us to distinguish debouchure and submarginal gravel heapings, which denote the position of the glacier's edge, from the gravel veins of the glacier's body, which denote its systemic circulation. The semi-morainic kames, forming peripheral belts, are the type of the one, the winding, branching windrows of gravel, the typical osars, form the standard of the other. Both classes have significant modifications and dependencies. The osars sometimes—probably much oftener than has been noted—end in osar fans, delta-like deploys of the gravel ridges at their lower extremities. The wonder is not so much that this should be, as that it should not oftener be. In similar manner the billowy kames merge into gravel plains. It is very common for these to be pitted with sinks, forming one of the several varieties of kettle holes. These pitted plains, of which this is but one type, constitute another of the singular, and not least puzzling features, of the assorted drift. They have a somewhat wide range, but find their most phenomenal development in Wisconsin, Michigan, Ontario and the coast of New England.

The kames also graduate into true moraines. In the progress of their accumulation they were thrust by the adjacent ice and heaped into ridges, as genuinely morainic as though made of unwashed material. In connection with the great terminal moraines, in favorable situations, there may be seen every gradation of washing and assortment, every form of kame-like and morainic heapings, every degree of stratification and every phase of disturbance. A thoughtful consideration of the drainage conditions at the edge of a glacier when pushing in an oscillatory way against a frontal ridge of débris and against its own drainage products, will relieve the mind of surprise at the enormous development of kame-like accumulations along the morainic tracts of the lower peninsula of Michigan and of eastern and northwestern Wisconsin.

Of the valley drift formed by streams heading on the glaciers and strewing glacial débris far down their courses, there is likewise a most complex series. The extreme phases are the most significant and can alone be noted. They embrace the moraine-headed valley trains, on the one hand, and the loess tracts on the other. The former are the deposits of the glacial floods when the slope gave impetus to the drainage; the latter are construed as the products of slack drainage.

Tracing the former up the valley toward the ice edge, the material becomes progressively coarser until it merges into an elevated, expanded head blending with the moraine from which it took its origin. The valley beyond the moraine is often much lower and quite free from similar deposits. The whole phenomena show that the gravel stream has a veritable head in the moraine.

Continuous with these and of the same nature and significance, are the glacial aprons of overwash drift that fringe the outer sides of the moraines in favorable situations. The name is the happy suggestion of Professor Shaler. Taking their origin high upon the exterior face of the moraines they slope down to more gently declining plains, gradually gathering into the great drainage lines of the region. It would be difficult to imagine phenomena that could point more unequivocally to a glacial origin than do the moraine-derived aprons and the moraine-headed streams of drift. Aside from their testimony to their own glacial origin, they indicate vigorous drainage conditions.

Contrasted with these evidences of vigorous drainage are the broad tracts of fine silt, designated loess, that occupy the Missis-

sippi as a great trunk stream, leading up the Missouri as far as southern Dakota, up its own valley as far as east central Minnesota, up the Illinois and Wabash as far as their great bends, and up the Ohio into southeastern Indiana. They are so correlated with the glacial drainage valleys and with the borders of the ice in the later stages of the earlier ice epoch—overlapping the earlier drifts and overlapped by the later—that the conclusion seems justified that they are products of glacial drainage of a fluvio-lacustrine character. This may not be true of all loess. This view is supported by the constitution of the silt, embracing as it does, fresh particles of dolomite and decomposable silicates undistinguishable from those that characterize glacial drift. In some regions the iceward border of the loess is abrupt and in eastern Iowa it is terminated by peculiar dome-like accumulations whose centres are sand, which graduates above into typical loess, which in turn connects itself with the common mantle of the region. These are the discovery of McGee and are perhaps to be placed in the category of debouchure phenomena under exceptional circumstances.

The drainage conditions which this interpretation of the loess involves, stand in marked contrast to those necessarily implied by the coarser valley gravels which head upon the moraines, and herein lies one of the important determinations of recent study, namely, the differentiation of the drainage conditions and the orographic attitudes of the two glacial epochs. While there are limited accumulations of loess in connection with the deposits of the later glacial epoch, they are confined to special limited areas and have a relatively insignificant development, while the extent of the loess mantle of the earlier epoch is much greater than generally recognized in the literature of the subject.

In addition to the products of glacial streams within and without the ice, passing note must be taken of the assorted deposits of glacier-fringing lakes. We have already noted the till-like phase of such deposits. We here add the laminated clays, sands, silts and gravels of wider extent and of less doubtful interpretation. They range in altitude from below the sea level to 3,000 feet and, by interpretation, beyond. They vary in areal extent from trivial valleys blocked by ice to the broad expanses of the great basins. If an attempt were made to enumerate all instances, great and small, and all stages, earlier and later, the list of localities and deposits would swell, not by scores and hundreds, but by thousands.

The great examples of these are the immense sheets of clays and

silts overspreading the great basins from the lower St. Lawrence to the great Winnipeg basin and the plains beyond, occupying thousands of square miles. They often present among their surest credentials, overflow channels to the southward, crossing divides often hundreds of feet above existing outlets, and varying in altitude among themselves at least 2,000 feet. Of the scores and hundreds of these overflow channels, the greatest are those of the Mohawk, discharging ancient Ontario; the Wabash, draining ancient Erie; the Illinois, giving outlet to ancient Michigan; the St. Croix, draining Superior; and the Minnesota, discharging extinct Lake Agassiz. There are some scores of lesser, but notable, importance along the St. Lawrence divide in New York, Pennsylvania, Ohio, Indiana, Illinois, and Wisconsin, and in Dakota, Montana, and the Dominion.

A second significant feature is the peculiar termination of these deposits on their iceward sides. The phenomena have as yet been but partially studied and have scarcely found a place in the literature of the subject, but are destined to constitute one of the permanent features of the more exact descriptions of the future.

A third great feature, better known and just now being industriously studied, is the change in altitude which the beach lines of these glacial lakes indicate. Not only did the surfaces of the lakes stand at altitudes greatly different from the present, but the surfaces themselves were tilted, if not distorted, as compared with the existing water levels. As a general rule, the ancient water levels rose to the north, as compared with existing ones, and the rate of rise has been shown by the trustworthy levellings of Upham and Gilbert to range from one to six feet per mile, and by less trustworthy barometrical observations it appears to reach beyond this. Data are being rapidly gathered in, which in their fulness it may be hoped will be competent to determine how much of this is due to ice attraction, how much to ice-weighting, how much to thermal changes, how much to intercurrent crustal changes independent of glacial presence, and how much to other and undiscovered causes. This is of the future, but we may reckon as a present possession the initial data and the inaugurated investigation.

If we turn from the glacial débris to the glacial floor, the phenomena of ice-scoring present unsurpassed richness and variety. There are ice-markings varying from lines of hairlike delicacy up through all grades of scratches, scorings, gouges and scrapings to great furrows so capacious as to be serviceable as roadways. There

are grooves of wonderful straightness and also of remarkable and almost inexplicable sinuosity; there are wonderfully continuous lines, contrasted with jumping gouges; there are attenuated origins and attenuated terminations; abrupt beginnings and still more sudden endings; there are scorings in various attitudes, on horizontal, on ascending, and on descending plains, on terraced surfaces, on rounded angles, on surfaces of horizontal or curved inclination, on vertically arched surfaces, on domes, on warped and on overhanging surfaces. There are striæ sharply characteristic of glaciers, and striæ indicative of floating ice; many of the former, few of the latter. The number of recorded observations of striæ reaches nearly 3,000.

If we turn to the more purely intellectual products that have sprung from the glacial phenomena, we find that our former somewhat ample and picturesque assortment of theories of the origin of the drift has become practically reduced to a single line, and that one the most bizarre of all—the glacial. With few exceptions, the active investigators of glacial phenomena in the United States accept as demonstrated the glacial origin of the greater mass of the drift of this continent. This is less true of Canadian investigators. Subordinate to this dominant hypothesis there are various degrees of belief respecting the extent of auxiliary glacio-natant agencies.

If we turn to the more profitable consideration of our working hypotheses, we find that our wealth has increased as our hypotheses of genesis have become fixed upon the fruitful glacial theory. The recent introduction of the strictly glacial methods in distinction from the earlier stratigraphical and pseudo-glacial methods, has been prolific in those fertile conceptions of action which are such powerful stimuli to investigation, such indispensable quickeners of the perception of the significance of phenomena and which are such vital aids in final interpretation. The working hypotheses necessary for the tracing out of moraines, the discrimination of the tills, the differentiation of the kames, osars and all that genus of fluvio-glacial products, and for the analysis of the drainage phenomena, have become rich beyond the limits of convenient statement.

If we turn from these theoretical aspects, which are the life and vitality of progress, to the broader and less essential speculations respecting the origin of the glacial epoch, I fear we shall find our wealth little increased. We have on hand practically the same old stock of hypotheses, but all badly damaged by the deluge of re-

cent facts. The earlier theory that northern elevation and geographical changes were the cause of glaciation appears to have been so far injured as to be practically valueless. The various astronomical hypotheses seem to be the worse for increased knowledge of the distribution of the ancient ice sheet. I think I speak the growing conviction of active workers in the American field that even the ingenious theory of Croll becomes increasingly unsatisfactory as the phenomena are developed into fuller appreciation. I think I may say this without prejudice, as one who, at a certain stage of study, was greatly drawn toward that fascinating hypothesis. But the more we know and ponder upon the enormous development of ice upon the plains of northeastern America, and contrast it with the relatively feeble development and dispersion from the mountainous regions of Alaska, which now bear the greatest glaciers outside of the Arctic regions, and the relative absence of such accumulations in northeastern Asia; in short, the more we consider the asymmetry of the ice distribution in latitude and longitude and its disparity in elevation, the more difficult it becomes to explain the phenomena upon any astronomical basis, correlated though it be with oceanic and aerial currents and geographical features by whatsoever of ingenuity. If we were at liberty to disregard the considerations pressed upon us by the physicists and astronomers and permit ourselves simply as glacial geologists to follow freely the leadings of the phenomena, it appears, at this hour, as though we should be led upon an old and forbidden trail to an hypothesis which our fellow scientists, more learned in those things than we, assure us is altogether untenable, namely, the hypotheses of a wandering pole. It is admitted that there is a *vera causa* for geographical changes of the pole in elevations and depressions of the earth's crust but it is held inadequate, though qualifiedly advanced by George Darwin. It is admitted that there is something remarkable in the apparent changes of latitude shown by the determinations of European and American observatories, but the trustworthiness of these is challenged. Could we discover adequate causes for geographical changes of the position of the poles, or were there no barriers against free hypothesis in this direction, glacial phenomena, as they now present themselves, could apparently find adequate explanation. But debarred, as we doubtless should consider ourselves to be at present, from this resource, all our hypotheses remain in greater or less degree inharmonious with the facts, and the riddle remains unsolved.

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PAPERS READ.

ON THE METHODS OF TESTING BUILDING STONES, BY ABSORPTION, FREEZING AND FIRE. By Dr. ALEXIS A. JULIEN, Columbia College, New York.

[ABSTRACT.]

SOME general results were first presented of an examination of the methods in common use for determining compressive strength and cross-strain and a brief statement of a new mode by which these factors may be obtained for *long-continued* pressure, such as prevails in actual construction.

1. *Absorptive power of a stone.* Three errors in the common methods; the use of roughly surfaced cubes; the idea of necessary relationship between weight and absorptive power; and that of the necessity of saturation of the whole body of stone.

The main object is to determine *avidity of superficial absorption*, and for this purpose, a new method of trial was described, in which a *measured surface* of stone is exposed to moisture and to wetting. The results of series of experiments were added, and also a table in which were summed up all the published figures for absorption, etc., for American building stones.

2. *Resistance to Frost.* In order to determine the action of frost, working alone, an apparatus was described, and the results were given of an experiment of forty-two natural successive freezings and thawings on a set of nearly all the building stones now used in New York City. The conclusion as to the special office of frost in disintegration was stated, and a new method for determining the true disintegration of exposed stone surfaces.

3. *Resistance to Fire.* The methods in present use were considered, and then the results given of a series of fire-tests, on many of the principal stones used in our Eastern cities, in regard to resistance to sudden and violent heating, to long-continued heating, and to sudden chilling by cold water.

THE TULLY LIMESTONE, ITS DISTRIBUTION, ITS IRREGULARITIES, ITS CHARACTER AND ITS LIFE. By Prof. S. G. WILLIAMS, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

THE Tully limestone has a considerable scientific interest from the fact that for nearly a hundred miles from east to west it forms an easily recognized plane of reference for the rock series of New York, besides being

the southernmost limestone of the state. First appearing as a distinct rock in Ontario Co., it extends eastward through nine counties to Chenango Co., where it disappears by passing into a calcareous shale, and by reason of the deeply eroded valleys of the lakes of central New York, causing long southward-reaching loops of the limestone, it has a length of outcrop of nearly 170 miles. Throughout this long extent it appears as an impure limestone, usually thick-bedded, and of a thickness varying from ten feet to a maximum of about thirty feet, its greatest thickness being found on Skaneateles Lake, and in the vicinity of Tully. On Seneca and Cayuga lakes it is affected by one considerable and several minor undulations the greater undulation being most marked on Cayuga Lake on the east side of which it forms an anticlinal arch of 230 feet in height and about four miles in span. The incorrectness of Vanuxem's explanation of this, as due merely to change of direction in the lake and so only apparent, is seen when the exposures of the flexed region on the west side of Cayuga Lake are plotted on an accurate map, and are found to form nearly a straight line. Besides these irregularities of the Tully, and the fault described by Mr. Berlin Wright in the 35th Regents' Report of New York, there are indications of a considerable anticlinal flexure near South Lebanon, Madison Co. The Tully has been found by merely incidental examination to be more fossiliferous than had been supposed, and a list of one hundred and twenty species has been made including one crinoid, sixteen corals, four Bryozoa, forty-two Brachiopods, sixteen Lamellibranchs, nineteen Gasteropods, one Pteropod, thirteen Cephalopods, seven Trilobites including Bronteus and one fish. Several of these species are doubtless new.

NOTE ON THE LOWER HELDERBERG ROCKS OF CAYUGA CO., NEW YORK. By Prof. S. G. WILLIAMS, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

IN this note I desire to add to the paper on the Lower Helderberg of central N. Y., published last year, the results of some further explorations in these rocks which have brought to light several additional species of fossils, some of them well-known Lower Helderberg forms while others seem yet to be undescribed. The number of species now known from this seventy-five feet of limestones, hitherto considered to belong to the Water Lime Group, is twenty-six, including such fossils of the Lower Helderberg as *Favorites Helderbergiæ*, *Lingula rectilatera*, *Orthis strophomenoides*, *Strophodontavari striata*, *Spirifera Vanuxemi*, *Rhynchonella semiplicata*, *Bionia* (*Anatina?*) *sinuata*, and *Oneoceras ovoides*, and representing all parts of the Lower Helderberg series from the Tentaculite to the Delthyrio Shaly Lime.

Hence there is no good reason to doubt that these impure limestones of Cayuga Lake, lying directly on the plaster-beds which I have already shown

belong to the Water Lime Group (Transactions of A. A. A. S. Philad., 1884), are the representatives in a simplified form of the varied Lower Helderberg series of eastern New York.

A REVISION OF THE CAYUGA LAKE SECTION OF THE DEVONIAN. By Prof. H. S. WILLIAMS, Cornell College, Ithaca, N. Y.

[ABSTRACT.]

REMARKS upon the relation of the different formations in the series, their thickness, faunas, etc., based upon a study of the sections exposed in the valley of Cayuga Lake, New York, with a suggestion of some points of revision of this standard Devonian section.

REMARKS ON THE MOLLUSCAN FOSSILS OF THE NEW JERSEY MARL BEDS, CONTAINED IN VOLS. 1 AND 2 OF THAT PALÆONTOLOGY, AND ON THEIR STRATIGRAPHICAL RELATIONS. By Prof. R. P. WHITFIELD, Am. Mus. Nat. Hist., New York, N. Y.

[ABSTRACT.]

GIVES a summary of the molluscan fauna of the several beds of the marls taken from tables prepared for the state palæontology, with a comparison of these with those of other states, showing what New Jersey forms have been recognized in several of the states where Cretaceous and Eocene formations occur. From these tables and summaries the geological horizons of the marl beds are shown to be equivalent to Nos. 4 and 5 of the Upper Missouri River section and to the Claiborne (Alabama) Eocene.

NOTICE OF GEOLOGICAL INVESTIGATIONS ALONG THE EASTERN SHORES OF LAKE CHAMPLAIN, CONDUCTED BY PROF. H. M. SEELY AND PRES. EZRA BRAINARD OF MIDDLEBURY COLLEGE, WITH DESCRIPTIONS OF THE NEW FOSSILS DISCOVERED. By Prof. R. P. WHITFIELD, Am. Mus. Nat. History, New York, N. Y.

[ABSTRACT.]

THIS is a notice of the discovery of new fossil remains of the bird's-eye limestone of New York at Fort Cassin, Vt., during geological investigations conducted by the persons named along the lake shore, amounting to more than all the forms previously known, which were nineteen in number,

the new forms recognized amounting to twenty-two and several undetermined ones. The new forms will be given only by name, with copies of the printed descriptions. Most of the specimens described can be in the room for inspection.

[The paper is an extract from Bulletin No. 8 of the Am. Mus. Nat. History, not yet published].

On devonian and carboniferous fishes. By Prof. J. S. Newberry, New York, N. Y.

[ABSTRACT.]

This paper includes descriptions of a series of remarkable placoderm fishes recently found in the devonian and carboniferous rocks of Ohio, and not yet fully characterized.

On the cretaceous flora of North America. By Prof. J. S. Newberry, New York, N. Y.

[ABSTRACT.]

This paper summarizes the results of recent collections and study of the American cretaceous flora, comparing the floras of different horizons and localities on this continent with themselves and with those of Greenland and Europe.

Preliminary geological map of that portion of Nebraska east of the 98th meridian. By Prof. L. E. Hicks, Lincoln, Neb.

[ABSTRACT.]

The writer explained the formations delineated upon the map and pointed out several corrections in the outlines of formations on maps of Nebraska, or maps including Nebraska, previously published, also lines never before drawn, as, *e. g.*, that between the Colorado and Dakota groups of the Cretaceous Period.

The permian formation in Nebraska. By Prof. L. E. Hicks, Lincoln, Nebraska.

[ABSTRACT.]

We find in Nebraska a series of limestones and marls overlying the Coal Measures and apparently distinct both in lithological composition and

fossil remains. The limestones are more magnesian than those of the Coal Measures. They contain numerous geodes and irregular cavities giving many of the layers a honeycombed appearance. Other layers are marked by the presence of masses and nodules of chert. The prevailing colors are blue, yellow and buff. A stratum of indurated marl near the middle is a characteristic feature. Above this marl are shelly and oölitic limestones. The total thickness may be 175 to 200 feet, though exact determinations cannot be made until the dip is more thoroughly studied. Along the Big Blue river from Beatrice to Holmesville, the dip is southeast. Along Indian creek from Wymore to Odell it is west. There are some indications of unconformability between the Coal Measures and the Permian, and between the Permian and Cretaceous there is extensive unconformity by erosion.

The author exhibited to the section a collection of fossils from this formation made by Mr. W. C. Knight. It included several new and very interesting forms. Of the 123 species described by Meek from the Coal Measures of Nebraska probably not more than ten, certainly not more than fourteen, extend upward into the Permian.

As regards the extent of this formation, previous maps have represented it as running north to the Platte river, but the author has not found it to extend more than half that distance from the Kansas line.

No doubt a great deal of error and confusion have marked the efforts hitherto made to differentiate the Permian from the Coal Measures, but this fact should not be allowed to prejudice any new and valid evidence. The author, however, uses the term Permian provisionally.

SOME TYPICAL WELL-SECTIONS IN NEBRASKA. By Prof. L. E. HICKS, Lincoln, Neb.

[ABSTRACT.]

1. THE well at Brownville was put down in search of coal. Four thin seams of coal were found, the most considerable one being thirty inches in thickness and 821 feet beneath the surface. This boring passed through 376 feet of Upper Coal Measures, 445 feet of Middle Coal Measures and 180 feet of Lower Coal Measures; total depth 1001 feet.

2. The well at Lincoln, Neb., was put down for water. Good fresh water (not artesian) was obtained at several points within 100 feet of the surface, at 244 feet strong brine and at 544 feet mineral water which flows out at the well-mouth abundantly. The first forty feet of this section was through soil and glacial drift, then 204 feet of the Dakota group Cretaceous period, then 741 feet of Coal Measures; total depth 985 feet. The fresh water and brine were cased off and the mineral water is much used medicinally, being aperient and tonic, and for bathing, several bath houses being supplied from the well.

Well near St. Helena.

Group	Strata	depth.	thickness.
COLORADO GROUP.	Chalky Limestone	25	25'
	Shale	59	34'
	Dark Blue Clay	329	270'
	Shale	369	40'
DAKOTA	Hardgrits and Black shale	399	30'
	LIGNITE		6"
			17½
			6"
	Sand and WATER Clay	466	48' 6"

Well at Lincoln.

Group	Strata	depth.	thickness.
	Drift	40	40'
DAKOTA GROUP.	Sands Clays Sandstones and Conglomerates [BRINE]	244	204'
COAL MEASURES.	hales Marls and Limestones Mineral	544	300'
	Water Limestones Shales and Marls Slate	902	358'
	COAL		6'
	Limestones and Shales	985	77'

Well at Brownville.

Group	Strata	depth.	thickness.
UPPER COAL MEASURES.	Shales Lime and Sandstones		93'
	COAL	93	8"
	Shales and Limestones		148'4"
	COAL	242	1'2'
	Shales Lime and Sandstones		132'10"
	COAL	376	10"
MIDDLE OR BARREN COAL MEASURES.	Limestones and Shales		444'2"
LOWER COAL MEA.	COAL	821	2'6"
	Shales Lime and Sandstones (Sea level)	1001	177'6"

3. The well near St. Helena was put down in search for coal. Two thin seams of lignite and much black shale simulating coal were found. A very copious artesian flow of good fresh water was obtained at about 400 feet from the surface in the loose sands of the Dakota group. This artesian feature of all these wells is due to the fact that Nebraska forms a portion of a great synclinal trough, the western rim of which is 3000 feet higher than the eastern.

At the top of this well 25 feet of soil, clay, and chalky limestone were passed through which, together with 344 feet of shales beneath, constitute the Colorado group of the Cretaceous period; then 97 feet of hard grits, black shales, lignite and loose sands of the Dakota group. Total 466 feet.

The accompanying sections give the salient features of these wells. [For the meeting the paper was illustrated by long sections carefully drawn to the scale of one inch to ten feet.]

THE LINCOLN SALT-BASIN. By Prof. L. E. HICKS, Lincoln, Nebraska.

[ABSTRACT.]

NEAR the city of Lincoln are several salt marshes, situated along Little Salt creek, Oak creek, Middle creek, and Hayne's branch, all of which are tributaries of Salt creek. The latter stream derives its name from the saltness of its waters occasioned by the overflow of the marshes discharged into its tributaries.

The brine of the principal marsh on Oak creek tests 25° by the salometer. It was boiled down in iron kettles by the early inhabitants, and afterwards manufactured on a larger scale, the output at one time amounting to from two to four tons per day. At present no use is made of the brine, but the Western Salt Manufacturing Company of Chicago are preparing to manufacture it on a large scale, chiefly by solar evaporation.

These salt marshes lie in sands of the Dakota group of the Cretaceous period. Recent borings have revealed the fact that at the bottom of the Cretaceous the brine is stronger (35° to 50°) than at the surface of the marshes. This salt-basin appears to be the remnant of an old Cretaceous sea-border salt-marsh, in which evaporation of sea water occasioned the salting of the sands as they were laid down.

PRELIMINARY NOTE ON SOME FOSSIL WOOD FROM THE CARBONIFEROUS ROCKS OF OHIO. By Prof. E. W. CLAYPOLE, Akron, Ohio.

[ABSTRACT.]

THE extreme difficulty of the study of palæobotany is the excuse for bringing incomplete work before the association. The task of rearranging the broken and scattered plants of Nature's fossil herbarium is a task

of almost hopeless intricacy. Though something has been done in this country in the investigation of the external structure of the coal plants, yet the occurrence of carboniferous wood in a state of preservation admitting of study is exceedingly rare on this continent. In Europe, owing to more favorable conditions of fossilization and more thorough investigation, specimens have been found which, in the hands of Williamson, Carruthers and others, have thrown much light on the structure of the stems of the carboniferous flora.

A silicified specimen from Holmes county, Ohio, was found to represent *Dadoxylon antiquius* which genus of taxine conifers is therefore met with in the Lower Carboniferous of Ohio.

Another from Highland county, Ohio, was identified as *D. Newberryi* belonging to the Hamilton group.

A third is also a specimen of *D. antiquius* and is converted into pyrites. It came from the base of the Berea grit of Ohio. Being pyritous it must be examined by reflected light. The ordinary coniferous (so-called) tissue is then distinctly seen, the disks appearing like small hexagonal spots. There is little doubt that this specimen also belongs to *D. antiquius*.

The next specimen is also pyritous and was obtained from the Salem coal of Ohio. It is not coniferous but evidently belonged to a woody stem of some kind. It shows woody fibre closely packed and slender medullary (?) rays resembling those of recent exogenous stems. It is not possible at present to identify this wood but it may represent that of Cordaites, the only known exogenous stem of that age. If not, it must be new.

In the next specimen from the same locality, the medullary (?) rays are continuous through the woody fibre, indicating another exogenous structure.

A single specimen indicates a connection between some of these fossils and the well-known coal-fossil Lepidodendron. The stem of this plant is known to have possessed a double woody cylinder capable of fossilization.

The last specimen, also pyritized, exhibits distinct endogenous structure. No fossils, indicating the existence of this group of plants, have hitherto been brought to light in America. It was referred provisionally to the palms whose existence in carboniferous days is thus rendered at least probable.

CAMBRIAN AGE OF THE ROOFING SLATES OF GRANVILLE, WASHINGTON CO., N. Y. By CHAS. D. WALCOTT, U. S. Geological Survey, Washington, D. C.

[ABSTRACT.]

THE gray, purple and green roofing slates in the vicinity of Middle Granville, N. Y., appear to be nonfossiliferous with the exception of a few annelid trails and possibly fucoids; but in some thin-bedded limestones,

interbedded in the slates, a fauna occurs that is identical, as far as known, with the fauna of the Middle Cambrian or Georgia formation as it occurs in Canada and in Rensselaer county, N. Y.

The species collected at the Middle Granville quarries are *Lingulella?* sp.? *Hyolithes Americanus*, *Hyolithellus micans*, *Microdiscus speciosus* and *Solenopleura nana*. Five miles to the north, a belt of thin-bedded limestone rests directly on the purple slates at Robert Hall's quarry and from it I obtained *Stenotheca rugosa*, *Hyolithes Americanus*, *H. communis*, *Microdiscus speciosus* and *Olenellus asaphoides*.

This fauna is pre-Potsdam and its stratigraphic position is shown in the introduction to Bulletin 30 of the U. S. Geological Survey.

West of the fossiliferous limestones, slaty rocks with interbedded silicious and calcareous layers extend about three miles all dipping eastward at an angle of about 45°. To the east a great thickness of greenish slates extends for several miles and if we allow for considerable faulting and folding, a thickness of several thousand feet will still remain. To this add the thickness of the strata containing the purple, gray and green roofing slates and the known strata west of the fossiliferous limestones, and there will be 10,000 feet or more of rock to be added to the Potsdam formation of the Adirondack region when estimating the thickness of the Cambrian formations of New York State.

This paper is merely a note on the discovery of the palæontologic evidence of the Cambrian age of the roofing slates of the Granville district. The extensions of the slates to the north and south are of the same age; although in parts of Washington county, slates of a later geologic age may exist. (The red slates are now known to be of the Hudson river formation.—C. D. W. November 15, 1886.)

THE NIAGARA GORGE. By Dr. JULIUS POHLMAN, Buffalo, N. Y.

[ABSTRACT.]

IN this paper the author advanced the opinion that a small ancient water-basin existed between the parallel east-west outcrops of the Niagara and the corniferous limestone in the neighborhood of the Falls, owing to the excavation of the softer shales of the intermediate Onondaga group. To the body of water thus formed, he proposed to give the name of "Lake Tonawanda." The drainage of this lake was, he considered, into the valley of Ontario, because the northern barrier was lower than the southern. The channel of this drainage was supposed to lie along the present Niagara gorge from the falls to the whirlpool and the well-known, old, drift-filled valley leading from the whirlpool to St. David's. Along this line the author thought that no great cataract existed but that three low falls with intervening rapids let the water down the great escarpment. One of these falls was over the Niagara limestone near the new suspension bridge; the second was over the Clinton limestone near the railway sus-

pension bridge and the third over the Medina sandstone near the whirlpool.

As the Ice age came on, this northward drainage was arrested and the water was compelled to find an outlet to the south over the corniferous limestone, and in so doing it excavated the present channel of the Niagara river to Lake Erie. Along this channel the water over the bar of the corniferous limestone is only twenty-four feet deep.

On the retreat of the ice the level of Lake Ontario was retained as that of Lake Erie, and the two subsided together as shown by a terrace at a height of 580 feet above tide round Lake Ontario, 600 feet above tide along the river and 610 feet above tide round Lake Erie; also by another about thirty feet higher along the same line; hence falls could never have existed at Lewiston.

As the water subsided the current of the river became more rapid but its task of excavating the lower gorge was light; for, in the author's opinion, a valley more or less deep had been already formed along the line of the present channel by an ancient stream flowing into the place of the whirlpool. The work of the present river has, therefore, been merely to clean out and deepen these old channels and the rate at which the excavation was accomplished must have been correspondingly rapid.

The popular opinion, therefore, that the Niagara river has cut its own gorge all the way from Lewiston to the Falls is, in the author's opinion, erroneous, for when the recession reached the whirlpool it found the old gorge of the Tonawanda and quickly cleaned it out. This explains why the river turns almost at right angles at the whirlpool. The three falls already mentioned were now reëstablished, but owing to the increasing thickness of the Niagara limestone, the two lower gained on the upper until finally they all became, as now, a single cataract in the channel of the preglacial Tonawanda.

ON THE RATE OF RECESSION OF THE NIAGARA FALLS AS SHOWN BY THE RESULTS OF A RECENT SURVEY. By R. S. WOODWARD, U. S. Geological Survey, Washington, D. C.

[ABSTRACT.]

THE paper consisted of the presentation of the results of a survey of the Falls just completed, and a comparison of its results with the surveys of 1842 and 1875, with accompanying remarks.

THE PLACE OF NIAGARA FALLS IN GEOLOGIC HISTORY. By G. K. GILBERT, U. S. Geological Survey, Washington, D. C.

[ABSTRACT.]

DURING the final northward retreat of the great ice sheet, lakes were held between the glacier front and the southern rim of the Laurentian

basin. One of these, covering parts of the Erie and Ontario basins, was several hundred feet deep where the Falls now are. Afterward it was rapidly lowered until the two lakes were differentiated and the shore of Ontario stood near Lewiston, less than 100 feet above the modern shore. By local relative depression of the land the water was carried slowly up to the Lewiston ridge, about 125 feet above the modern shore. By change of outlet due to ice retreat its surface was then carried somewhat lower than now and by a final change of outlet it was dropped (opposite Lewiston) to at least 100 feet below the present level. Local relative depression of land has finally brought about the present status. The Niagara river came into existence when the lakes were parted and the erosion of the gorge began. The definiteness of this epoch gives zest to the attempt to estimate subsequent geologic time by the aid of observations on the recession of the Falls.

The rate of recession proper to consider is that of the central third of the Horseshoe and that has fallen back 200 feet in forty-four years. If the past rate was the same, 7000 years were needed to excavate the six miles of gorge from Queenstown Heights. Various considerations qualify this estimate. Probably a certain amount of excavation was performed by preglacial or interglacial drainage in the vicinity of the Whirlpool; six miles is therefore an over-estimate of the distance trenched by the Niagara. At stages of recession earlier than the present there was a thinner body of limestone to be undermined and removed; there was a deeper exposed body of shale; the water plunged from a greater height; the water was concentrated in a narrower channel; it carried more floating ice; and all these differences tended to make the rate of recession faster. The rate may also have been influenced by variations in the amount of detrital load (a tool of erosion), by variations in the solvent power of the water, and by variations of its volume due to changes of climate or catchment basin. The catchment basin was formerly extended by including part of the area of the ice sheet; it may have been abridged by the partial diversion of Laurentian drainage to other courses. The problem admits of expression in an equation:

$$\text{Age of gorge} = \frac{\text{Length of gorge}}{\text{Rate of recession of falls}}$$

— effect of antecedent drainage,
— " " thinner limestone,
— " " thicker shales,
— " " higher fall,
— " " narrower cross-section,
— " " more floating ice,
± " " variations of detrital load,
± " " chemical changes,
± " " changes of river volume.

BUFFALO AND CHICAGO. By Prof. E. W. CLAYPOLE, Akron, Ohio.

[ABSTRACT.]

BUFFALO is the outlet port for the Great Lakes; Chicago is the port at the head of navigation. This relationship depends on geological causes that existed before either city was founded.

The four upper lakes consist of a large part of all the fresh water on the globe, banked up on a table-land five to six hundred feet above the sea. By a remarkable coincidence there are two points in the rim of this basin almost on the same level, Black Rock and Chicago.

The water-shed behind Chicago is so low that a dam twenty-five feet high across the river at Black Rock would throw the water of the lakes into the Mississippi; Buffalo would be at the head of navigation and Chicago the outlet port.

But the alluvial strata on Goat Island and along the river banks prove that formerly the water in the river was much higher than now, and the retaining dam was the Ridge of Queenstown Heights, forty feet above Lake Erie. In the latter part of the ice age, this ridge was lower than now, low enough to cause the outflow to be here instead of at Chicago, which is now fifteen feet below it.

In addition to this, the channel of Mackinac, lying so far north was closed by the ice, so that communication between lakes Huron and Michigan was cut off. Thus even without the glacial depression the passage of the river by Black Rock was determined. This is a curious illustration of what may be called geological equilibrium, where the difference of a few feet might have diverted the drainage of a large extent of country. (See Am. Naturalist, Oct., 1886.)

MECHANICAL ORIGIN OF THE TRIASSIC MONOCLINAL IN THE CONNECTICUT VALLEY. By W. M. DAVIS, Cambridge, Mass.

[ABSTRACT.]

OBSERVATIONS that will elsewhere be published in detail give reason for believing that the greater part of the trap (dolerite and diabase), that forms so characteristic an element of the Connecticut valley triassic formation, was poured out in broad sheets as contemporaneous lava overflows at certain times during the deposition of the sedimentary beds; and that intrusive sheets, in general conformable to the strata between which they have been driven, are relatively few in number and are chiefly limited to the western side of the formation in Connecticut. The present attitude of the formation may be described as a faulted monoclinal; the dip is nearly always eastward, fifteen to thirty degrees, but the continuity of the beds is interrupted by the occurrence of numerous faults, running about parallel with the strike of the beds, and with upthrow of variable amount on the east. The formation is thus divided into long, relatively narrow blocks,

running about north and south, the strata in all the blocks being canted over to the east. The repetition of beds, caused by the upthrow of the faults always being on the side of the direction of dip, allows a moderate thickness of strata to cover a broad surface area; greatly simplifies the scheme of eruptive action by correlating many different trap ridges as the outcropping edges of only four or five trap sheets; and gives a systematic structural interpretation to a complicated topographic form.

The mechanical origin of the faulted monoclinal offers an interesting problem for investigation. It cannot be referred to original oblique deposition, or cross-bedding on a large scale, as has been suggested, because heavy conglomerates occur on the eastern margin of the formation, dipping towards the ledges from which they were derived. A disturbance contemporaneous with the process of deposition is excluded by the occurrence of faults, which require continuity of their corresponding members across broad areas before the disturbance took place. The monoclinal attitude cannot be ascribed to the eruption of the trap; for the greater part of it was poured out conformably on the bedded rocks during their accumulation, and hence passively suffered disturbance at some later date: nor can the intrusive sheets have been the cause of the monoclinal; for the dip of the strata does not vary significantly on approaching the intrusions; and the topography of the intrusive trap ridges is so closely like that of the overflow trap ridges that the structure of both must be referred to a single cause: this implies that the intrusions as well as the overflows took place while the formation still lay horizontal, and that the whole mass of beds, igneous as well as aqueous, was afterwards deformed by some external force.

The close relationship of the triassic monoclinals in different districts suggests that the external disturbing force acted over an area much wider than that covered by the triassic strata, and penetrated to a depth much greater than their thickness. The distribution and attitude of the several triassic areas suggest that their deformation was controlled by a late manifestation of the same great compression forces that had at earlier periods produced the folds of the Appalachian system. It may therefore be profitable to inquire into the effects of an irresistible, east and west, horizontal compression acting to great depths on the pre-triassic rocks, leaving the relatively superficial unconformable cover of triassic strata to adapt itself as well as it can to the disturbance of the surface on which it rests.

The fundamental rocks of southwestern New England are schists and gneisses, of irregular dip and strike; but in the region of the Connecticut valley, their strike is generally a little east of north and their dip is nearer vertical than horizontal. This part of the earth's crust may therefore be regarded as composed to a great but unknown depth of vast slabs of crystalline rocks, varying in thickness, texture and composition; the triassic beds overlie them unconformably, spreading across the upturned edges of the slabs that were bevelled off to a tolerably even, horizontal surface by pre-triassic erosion. When the whole mass was crushed, so as to diminish its measure from east to west, it may be supposed that one of the

easiest ways of yielding to the crush was by a little slipping of slab on slab, whereby their inclination should steepen and their horizontal measure decrease. If the crushing were more severe near the surface than at great depths, a shearing force would be introduced that might, if necessary, throw the slabs over past the vertical and thus produce reversed dips. As slab slips on slab, the formerly horizontal bevelled surface of every one is canted over so as to dip in one direction at an angle equal to the change of the inclination of the slabs; and the surface of every slab is separated from that of its neighbors by faults with upthrow on the side of the direction of dip. The triassic cover is not strong enough to bridge across from ridge to ridge of the uneven surface thus produced; its weight is much greater than its strength can bear, and it perforce follows the deformation of its foundation, and thereby acquires a faulted monoclinal attitude. The explanation of the triassic monoclinal may therefore be included in the following general statement. Wherever unconformable masses are deformed together, the structure given to the lesser, relatively superficial mass must depend in great part on the changes in the surface shape of the greater, deeper mass below.

The tests thus far applied to this hypothesis are satisfactory, inasmuch as they correlate structures that were not before perceived to be dependent on one another: indeed the hypothesis has in one case allowed the prediction of sub-triassic structure from triassic form.

The most essential correlation is that between the strike of the sub-triassic schists and the trend of the triassic faults. This was perceived to be necessary, as soon as the hypothesis came to mind; and on examining Percival's map in his geology of Connecticut, 1842, it was found to be so distinct as to be almost self-evident. A broad belt of schists, with unusually regular strike about north-northeast, approaches and runs under the triassic strata at their southwestern margin, and seems to reappear on the other side of the formation, with the strike still in about the same direction: it is therefore probable that the belt is continuous beneath the overlying beds. The Hanging Hills and other trap ridges lie directly in the path of the belt, and are broken by oblique faults that trend about north-northeast, in perfect correspondence with the strike of the schists beneath.

A second correlation gives simple interpretation to one of the notable peculiarities of triassic topography. The ridges, formed on the outcropping edges of the several parts into which a single sheet of trap is divided by faults, are frequently offset or overlapped so as to stand conspicuously out of line with one another. When the northern of two ridges stands west of the line of the southern, the overlap may be called "advancing" and the ridges succeed one another in "advancing order," following Percival's terminology: the opposite overlap is "retreating." Remembering that the dip of the beds and the upthrow of the faults are to the eastward, a simple correlation is found between the order of overlap, on the one hand, and the angle that the trend of the fault makes with the strike of the trap sheets, on the other. When the strike runs to the left of the fault-line, the overlap is advancing; when the strike runs to the right of the fault-

line, the overlap is retreating. Illustration of this is given in Percival's geological map, and is abundantly found between Hartford and the Sound. A single fault may cause an advancing overlap at the southern end of a crescentric trap ridge, and a retreating overlap at the northern end. This correlation may be extended so as to connect the order of overlap with the strike of the underlying schists, and it was on this basis predicted that the schists beneath the range of the Barndoor Hills, which run through Granby and Simsbury, overlapping in receding order, should strike north in Granby and west of north in Simsbury. Their strike is not represented on Percival's map, but a search through his text discovered a description of the schists a little west of these ridges, with strike precisely as foreseen.

The structure of the Connecticut valley triassic formation as here described and the hypothesis presented in favor of it therefore appear to have a number of points in their favor, which may be summarized as follows.

The process of accumulation is much simplified, especially with respect to the igneous rocks. The material accumulated is economically repeated so as to cover a considerable area. The present structure results from a single operation of a simple mechanism, whose effects are in accord during a long period of time, over a large area of country, and through a great depth of dissimilar rocks. Curious details of topography require no especial provision for their explanation, but follow naturally and may be even predicted from the general process of deformation.

SOME NEW GEOLOGIC WRINKLES. By G. K. GILBERT, U. S. Geological Survey, Washington, D. C.

[ABSTRACT.]

IN Jefferson and Chatauqua counties, N. Y., there have been observed small anticlinal ridges involving strata otherwise little disturbed. Their relations to glacial deposits and striation show them to be of post-glacial origin and they are believed to have arisen from the horizontal expansion of superficial strata consequent on post-glacial amelioration of climate.

THE STROPHOMENIDÆ: A PALÆONTOLOGICAL STUDY OF THE METHOD OF INITIATION OF GENERA AND SPECIES. By Prof. H. S. WILLIAMS, Ithaca, N. Y.

[ABSTRACT.]

THIS paper presented (*a*) the characters separating the Strophomenidæ as a family from other brachiopods and showed (*b*) what were the first genera to appear geologically and wherein consist their distinguishing characters;

and (*c*) took the typical genera at their initiation, noted their distinguishing differentia, pointed out how some characters are generic at first, some specific, showed the nature and extent of the plasticity of these characters at the initial stage, and considered what it is that constitutes the well-defined genus and species and their relations to the history of the group as a family.

A TRILOBITE TRACK ILLUSTRATING ONE MODE OF PROGRESSION OF THE TRILOBITES. By EUGENE N. S. RINGUEBERG, M.D., Lockport, N. Y.

[ABSTRACT.]

DESCRIPTION of specimen found at Lockport, N. Y., from the upper portion of the Medina group. The tracks are in the form of regular succeeding series of ten paired divergent indentations arranged in two diverging rows with the tail trail showing intermittently between. This showed that the animal had progressed by means of a series of jumps. The method of the production of the markings was then explained by a comparison with the Ohio trilobite figured by Mickleborough showing that the ten strong thoracic limbs were the ones used. The ventral limbs being inactive in this form of locomotion.

THE DEEP WELL AT AKRON, OHIO. By Prof. E. W. CLAYPOLE, Akron, Ohio.

[ABSTRACT.]

IN this paper an account was given of the section exposed in drilling a deep well for natural gas at Akron, Ohio. The strata passed through were shown in a diagram and compared with similar sections in other parts of northwestern Ohio. Little gas was found.

ON SOME DYNAMIC EFFECTS OF THE ICE SHEET. By FREDERICK J. H. MERRILL, Columbia College, New York, N. Y.

[ABSTRACT.]

ALONG the belt of tertiary and quaternary strata, which on the southern New England coast is known to us in Long Island, Block Island, Martha's Vineyard, Nantucket and Cape Cod peninsula, extend two morainal ridges first accurately traced out by Warren Upham. These ridges throughout most of their extent differ from moraines elsewhere in the fact that there is but little glacial drift on them and their elevation is almost everywhere dependent on the existence of anticlinal folds in the stratified beds which

coincide in direction with the morainal ridges. That these folds have been produced by the lateral thrust of the ice sheet we cannot doubt, since their general trend is at right angles to the direction of glacial motion indicated by the striæ on the rocks of southern New England and they do not occur south of the southern range of morainal hills. There is good evidence to show that the deep bays on the north shore of Long Island have been excavated by the ice sheet and that the highest hills are partly formed of the debris from these excavations. On Gardiner's Island and at Sankaty Head the strata containing post-pliocene fossils have been tilted and folded by the glacier and a thin layer of drift has been deposited over them.

Conclusions: 1. The glacial drift forms a very small portion of the islands in question. 2. The morainal ridges are mainly ridges of upheaval. 3. The stratified deposits containing post-pliocene fossils are much older than the Champlain period.

VEINS OF SOUTHWEST COLORADO. By DR. THEO. B. COMSTOCK, Champaign, Ill.

[ABSTRACT.]

REFERENCE to statements in previous papers presented at this meeting to explain geological structure and history was followed by a statement of the unique distribution of veins and ores. An explanation followed of the origin of the fissures by faults, etc., with evidences of the mode of filling and some reasons why the theory of *local* segregation is untenable, except in special cases, which, however, also exist in this region.

More fully stated in *Geology and Vein Structure of Southwest Colorado.* Paper before Am. Inst. M. E., Feb., 1886, with four maps.

REMARKABLE OCCURRENCE OF ROCK CRYSTAL IN THE UNITED STATES. By GEORGE F. KUNZ, Tiffany & Co., New York, N. Y.

[ABSTRACT.]

ALTHOUGH we have in the United States a number of localities where quartz is found as cabinet specimens, of such a character as to give the localities a world-wide reputation, such as the old exhausted Ellenville lead mines, the pellucid crystals with and without cavities, containing liquids, bitumen, pearl spar and other substances, the magnificent groups from Arkansas that are in part entirely free from flaws but in nearly all instances with polished faces, the wonderful modified crystals from Alexander and Burke Cos., North Carolina, yet as a source of supply for large masses suitable for cutting, we have as yet yielded very little material. It is only an occasional mass that is sufficiently clear and flawless to cut even a two-inch

crystal ball. Several localities in North Carolina, Sharpstownship and White Plains have afforded these, and a mass slightly yellow was found in northern Georgia that would produce a three-inch ball.

Recently, however, a mass of rock crystal (only a fragment of the original crystal), that had been found at a new locality in the south near Cave City, Virginia, was sent to Messrs. Tiffany & Co. This, owing to its really enormous size, is worthy of note. Only parts of two prism faces were visible on the piece, yet it weighed fifty-one pounds and it was entirely pellucid with only an occasional feather, produced mainly by the breaking up of the original crystal by the finder, an ignorant mountain girl. The information coming with it was that the crystal which was thus ruined had weighed about 300 pounds; and, from the size and appearance of this fragment, there can be doubt that this information is correct. From all appearances, it would have afforded slabs of pure crystal which would have measured fully one foot in diameter had it not been thus ruthlessly destroyed. As it is, it may cut into slabs eight inches square and almost flawless, or cut into several spheres measuring from two to five inches in diameter, or into one 6½ or 7-inch ball not flawless, but yet remarkable from any locality. This is undoubtedly the finest mass of crystal ever found in the United States, and the promised developing of the locality may bring as fine masses to light as have ever been found in Switzerland.

In this connection may be mentioned a crystal of smoky quartz thirteen inches in length and five inches in diameter, from Pike's Peak, Colorado. This is transparent and perfectly free from flaws in the central part so as to afford a flawless ball four inches in diameter. This was found at a depth of 90 ft., and about 1,000 lbs. more were secured in addition to the above-mentioned crystal.

REMARKABLE IMPRESSIONS ON SYENITE. By Prof. WM. H. PITT, Buffalo, New York.

[ABSTRACT.]

THE original may be seen in the rooms of Buffalo Natural Science Society. The rock is a bowlder of hornblendic granite found in Erie Co., N. Y. These casts resemble organisms of the echinoid type.

Photographs of the impressions were exhibited.

REMARKS ON THE "PETRIFIED FOREST" OF ARIZONA. By Rev. JOHN DICKINSON, Pittston, Pa.

[ABSTRACT.]

A BRIEF description was given of the region where the petrified trees are found, the character of the locality in respect of its topographical and geological features with remarks on the prominent characteristics of the material itself and of the volcanic ash and sandstone in which it is embedded. The description was illustrated with specimens brought from the place.

ON CERTAIN LIMESTONES OF COLUMBIA CO., N. Y., AND THEIR RELATION TO THE SLATES OF THE TACONIC SYSTEM AND THE SHALES OF THE HUDSON RIVER GROUP. By IRVING P. BISHOP, Chatham, N. Y.

[ABSTRACT.]

THIS paper contains the description of certain limestones of Columbia co., N. Y., their extent as traced by the writer, and their relation to the rocks east and west. In the limestones the writer has discovered fossils of the Trenton age. He infers a synclinal near Chatham with this Trenton limestone pushed up on either side.

GEOLOGY OF FLORIDA. By J. KOST, Tallahassee, Fla.

[ABSTRACT.]

1. THE geology of Florida has generally been misrepresented and consists not simply of a long stretch of sand deposited on a bed of recent coral.

2. Coralline rock is not even the chief characteristic of the rocks of Florida; but shell-rock, coquina, on the east of the St. Johns, and an arenaceous shelly limestone in the other portions. Silicious material is abundant.

3. Large tracts of clay deposit appear in various parts of the state; this contains disseminated iron and in a few localities good iron ore-limonite.

4. Eocene tertiary with its characteristic nummulitic limestone is found in somewhat extended sections in divers parts of the state.

5. Miocene with its characteristic fauna and flora appears in several localities in the central portions of the peninsula.

6. Pliocene, or at least quaternary formation, is present, not only along the coast, but in other parts of the state, as the remains of the mastodon and elephant have been recovered in several localities as also those of other mammalia common to the quaternary.

7. Large or rather variously distributed lacustrine localities appear, having fresh-water fossils intermingled with land shells and fossils of amphibians.

8. A theory is projected in the paper as to the source of the material of the clays of Florida.

9. Data are given indicating something of the chronological order and synchronal relations of the Florida rocks.

PRELIMINARY NOTE ON THE SUCCESSION OF THE CRYSTALLINE ROCKS AND THEIR VARIOUS DEGREES OF METAMORPHISM IN THE CONNECTICUT RIVER REGION. By Prof. B. K. EMERSON, Amherst, Mass.

[ABSTRACT.]

A COMPARISON of the Bernardston fossiliferous section with the successive bands of the same series eastward, where the metamorphism gradually increases.

THE AGE AND CAUSE OF THE GORGES CUT THROUGH THE TRAP RIDGES BY THE CONNECTICUT AND ITS TRIBUTARIES. By Prof. B. K. EMERSON, Amherst, Mass.

[ABSTRACT.]

THE gorges were cut by the preglacial drainage and the streams were restored to their old course by the positions of their deltas.

REMARKABLE EXTINCT GEYSER-BASIN IN SOUTHWEST COLORADO. By Dr. THEO. B. COMSTOCK, University of Illinois, Champaign, Ill.

[ABSTRACT.]

THE geographical and geological features of southern Colorado are, in many respects, remarkably similar to those of northern Wyoming. In fact, there are seven well marked culminating points in the relief of N. America about which different volumes of geological history have been arranged. To these centres of development I have elsewhere referred (here quoting papers) and more than once I have had occasion to note the striking resemblances above mentioned.

The Red Mountain mining district, chiefly in Ouray co., Colo., is the seat of an ancient geyser-basin of wonderful interest. The development of the mines is gradually throwing new light upon the subterranean structure. Numerous geyser-mounds of gigantic size dot the surface and the whole basin is made up of the deposits from thermal springs, mainly silicious, which, when in action, far exceeded the greatest of the existing geysers of the Yellowstone Park.

Here follows a description of the district and its mounds with comparisons between the two districts named, to which is added an explanation of the structure which has made the Red Mountain area rather unique. This introduces the subject of super-metamorphism which is more fully treated in a succeeding paper by the author.

(Paper published in Amer. Nat., Nov., 1886.)

SUPER-METAMORPHISM; ITS ACTUALITY, INDUCING CAUSES AND GENERAL EFFECTS. By Dr. THEO. B. COMSTOCK, University of Illinois, Champaign, Illinois.

[ABSTRACT.]

THE Rocky Mts. in Montana, Wyoming and Colorado, are remarkably uniform in geognostic features. A brief review follows of the general geological history. The thickness of the palæozoic deposits varies at different points, but with a gradual reduction southwards, etc. In the north the Silurian and Devonian terranes are well-developed and well preserved, though baked or hardened in some instances. In the south, the same deposits occur also, but in southern Colorado they have nearly or quite disappeared.

Here is introduced evidence to show that excessive metamorphism and final conversion into granite and quartzite have occurred, followed by a reasonable explanation of the inducing causes and the final results, with reference to a succeeding paper to be read at this meeting upon a theory of *Volcanism*.

HINTS TOWARDS A THEORY OF VOLCANISM. By Dr. THEO. B. COMSTOCK, Champaign, Ill.

[ABSTRACT.]

REFERENCE was made to preceding paper on super-metamorphism showing the effects of that principle as exemplified in Wyoming and Colorado. Review of volcanic activity in these sections showing an apparent reason for Richthofen's classification of volcanic rocks and hinting of the reason for a uniform succession. The whole illustrated by examples from Colorado and Wyoming tracing the gradual changes southward.

PECULIARITIES OF THE DRIFT OF THE ROCKY MOUNTAINS. By Dr. THEO. B. COMSTOCK, University of Illinois, Champaign, Ill.

[ABSTRACT.]

THE glacial period was characterized in the Rocky Mts. by local action with a general relation to the great ice sheet, the effects still being evinced by existing glaciers. In different parts of the chain there were different results.

Here follow descriptions of the bowlder and iceberg drift of Wyoming, the special deposits in Colorado and especially a review of the *pouch-drift* of southwestern Colorado. This latter is a peculiar type not previously discussed in detail. The relation of "timber-line" to the glaciation was also noticed.

(Paper mainly given in *Amer. Nat.*, Nov., 1886.)

THE HOLYOKE RANGE ON THE CONNECTICUT. By Prof. B. K. EMERSON, Amherst, Mass.

[ABSTRACT.]

A DETAILED map was exhibited showing the complex faulting of the main sheet of diabase, the position of the heavy bed of diabase tufa which marks the second epoch of volcanic activity and the position and extent of a series of small volcanic plugs which penetrate the sandstone along a

line parallel to and south of the outcrop of the main sheet and apparently along the fissure through which the earlier diabase came.

Contact inclusions at the base and at the surface of the great sheet were described and the peculiarities of the later diabase detailed.

This consisted in the perfect freshness of the mass, the large amount of glass mass and of a very ferruginous olivine and the enormous amount of included granitic sand.

This had special reference to a single one of the later craters, the second east from the river.

THE CRITICISMS OF THE ANTICLINAL THEORY OF NATURAL GAS. By Prof. I. C. WHITE, Morgantown, W. Va.

NOTE ON THE ARCHÆAN ROCKS OF THE HIGHLANDS EAST OF THE HUDSON RIVER IN NEW YORK. By Prof. J. C. SMOCK, Albany, N. Y.

FOSSILS FROM THE TACONIC. By Prof. J. D. DANA, New Haven, Ct.

PALÆONTOLOGICAL OBSERVATIONS ON THE LIMESTONES OF THE TACONIC SERIES OF CANAAN, COLUMBIA CO., N. Y. By Prof. W. B. DWIGHT, Poughkeepsie, N. Y.

QUATERNARY PHENOMENA ABOUT THE HEAD OF CHESAPEAKE BAY. By Prof. W J M'GEE, U. S. Geological Survey, Washington, D. C.

TOPOGRAPHY ABOUT THE HEAD OF CHESAPEAKE BAY. By Prof. W J M'GEE, U. S. Geological Survey, Washington, D. C.

SOME NEW TERRESTRIAL FACTS BEARING ON THE DATE OF THE CLOSE OF THE LAST GLACIAL PERIOD. By Prof. G. F. WRIGHT, Oberlin, Ohio.

ROUNDED BOWLDERS AT HIGH ALTITUDES ALONG SOME APPALACHIAN RIVERS. By Prof. I. C. WHITE, Morgantown, W. Va.

SECTION F.

BIOLOGY.

ADDRESS

BY

PROF. H. P. BOWDITCH,

VICE PRESIDENT, SECTION F.

WHAT IS NERVE-FORCE?

EVER since I learned that the honor which had been conferred upon me of presiding over the section of biology involved the constitutional obligation of producing an opening address, I have been led to speculate upon the wisdom of the provision which compels a presiding officer thus to occupy the time of his section with formal remarks.

In the early days of the Association it may have been found desirable to stimulate the literary activity of the members, and to secure by a constitutional provision the presentation each year of a certain number of more or less carefully prepared papers; but now, when time can scarcely be found for the discussion of the really valuable papers awaiting consideration, a chairman would indeed show himself strangely insensible to the duties of his post who should, by perfunctory remarks of his own, long detain his section from the important work which has called them together.

I would not of course be understood as speaking disparagingly of the addresses of former vice presidents in this and other sections of the Association. It is doubtless true that many valuable contributions to science have found their way to the public through the medium of an annual address, but it may be fairly asked whether these same contributions would not have been made through some other channel if the writer had not found himself thus called upon to address his section.

A worker in the field of science who has a message which he

feels called upon to deliver to his brethren is sure to find some means of making himself heard; nor can it be said that a volume of transactions, even of such an active association as our own, offers a particularly favorable medium for such a communication. In fact, the special journals of science, in the promptness of their appearance and the extent of their circulation, have such an advantage over the transactions of an association as channels for the conveyance of scientific thought, that it is not uncommon to hear the exaggerated opinion expressed that an article might as well not be printed at all as buried in a volume of transactions.

But whether volumes of transactions or special journals are the chosen medium of communication, it is clear that the literary activity of workers in science needs no stimulation at the present time. The constantly increasing difficulty which specialists, even in quite narrow fields, find in keeping themselves posted with regard to progress in their lines of work is a sufficient proof of the correctness of this statement.

The accumulated literature in every department of science is already so enormous in amount and is increasing at such a rapid rate that any association or individual undertaking to contribute thereto should do so only under a sense of grave moral responsibility.

Under these circumstances is it not desirable for the members of this Association to consider whether the best interests of science would not be served by so amending the article of the constitution, which requires annual addresses by the vice presidents, as to make it permissive and not mandatory in its provisions?

Having thus entered my protest against a system which places me before you in the position of one who has got to say something rather than of one who has got something to say, I will proceed to comply with the regulation and will ask your attention for a few moments to some of the evidence which has been recently collected relating to one of the most important problems of physiology. A distinguished biologist has remarked with great truth that the study of the nervous system is the true field of battle for physiologists, all other investigations, however interesting and important, being of the nature of skirmishes, preparatory for and leading up to the final conflict in which we must engage before we can hope to gain a position from which nature's most mysterious processes are laid bare to our view. Of all the functions of the nervous system,

the one which at first sight would seem most accessible to investigation is that of the nerve fibre itself. What conception can we form of the physical or chemical changes which take place in those white glistening bands which are for us the only channels through which knowledge of the physical universe can be obtained and which also enable us to impress upon the world around us the evidence of our conscious personality?

From the earliest times this problem has been earnestly discussed by physiologists but I do not intend to weary you with an account of the various crude theories which have been from time to time advanced. With the discoveries of Du Bois Reymond, the hope arose that nerve activity might be explained as an electrical phenomenon and the attempts made to build up a satisfactory electrical theory of nervous action have been numerous and ingenious. The important facts which forbid the identification of nerve force with electricity are the absence of an insulating sheath on the nerve fibre, the slow rate at which the nerve force is transmitted, and the effect of a ligature on a nerve in preventing the passage of nerve force while not interfering with that of electricity. The electrical phenomena connected with the functional activity of nerves (action current, electrotonus) appear, therefore, to be secondary in their character and not to constitute the essential process in nerve action. In this connection should be noted an experiment of d'Arsonval[1] which shows how the electrical phenomena associated with the activity of nerves may be imitated by purely physical means. This observer filled a glass tube of one or two millimeters interior diameter with drops of mercury alternating with drops of acidulated water, thus forming a series of capillary electrometers. The tube was closed at its two ends with rubber membranes and was provided with lateral openings by which its interior could be connected with electrical conductors. A blow upon one of the membranes caused an undulation of the liquid column which was propagated from one end to the other of the tube and was accompanied by a wave of electrical oscillation which was propagated *at the same rate*. The phenomenon is, according to d'Arsonval, to be explained as follows: The blow upon the membrane changes the form of the surface of contact between the first two cylinders of mercury and acidulated water. This change of form is transmitted to the following cylinders with a rapidity dependent upon the na-

[1]Comptes rendus de la Soc. de Biologie, Apr. 3, 1886.

ture of the fluid. But each of these changes of shape is accompanied by the production of an electric current (Lippmann's phenomenon or variation of superficial tension) and the tube is therefore traversed by an electric wave which necessarily has the same rate as the undulation of the liquid column. The analogy between this phenomenon and the wave-like propagation of the action current in nerves is sufficiently obvious.

In studying the nature of nerve force two alternatives present themselves. We may conceive the impulse to be conducted through the nerve fibre by a series of retrograde chemical changes in the successive molecules of the nerve substance, the change occurring in one portion of the fibre acting to produce a similar change in the neighboring portion. As this process is associated with the using up of organic material and the consequent discharge of potential energy in the successive portions of the nerve, the theory may be called *the discharging hypothesis.* The burning of a line of gunpowder may be taken as an example of this sort of action.

On the other hand, we may conceive that the nerve force is transmitted from molecule to molecule by some sort of vibratory action as sound is transmitted through a stretched wire. As this theory does not involve the using up of any material but simply the transferring of motion, it may be called *the kinetic hypothesis.*

Let us now enquire what evidence can be obtained in favor of one or the other of these hypotheses by the study of the changes which are associated with the activity of nerves.

Inasmuch as the discharging hypothesis involves the destruction of organic material we may, if this theory be correct, reasonably expect to find in the active nerve fibre evidences of chemical decomposition and of heat production. Morever if the organic substances are used faster than they are replaced, or their products of decomposition removed, as would naturally be the case under constant stimulation, we may expect to observe a diminution of nerve action during the continuance of the stimulation: in other words we shall have the phenomena of fatigue.

On the kinetic hypothesis, on the other hand, we may expect to find an entire absence of chemical decomposition and fatigue and, if the moving particles are endowed with perfect elasticity, an absence also of heat production.

We must therefore consider what results have been reached by the experimental study of these three subjects, viz., the chemical

changes, the heat production and the fatigue of active nerve fibres, and ascertain whether these results are more favorable to a discharging or a kinetic theory of nerve action.

Chemical Changes.

The only functional chemical change of nerves for the existence of which an experimental proof has been offered is the change in the reaction to test paper. Just as the normally alkaline tissue of muscles becomes neutral or acid in activity, so, according to Funke[2] and Ranke[3], do nerve fibres and the white substance of the spinal cord change in activity from an alkaline to an acid reaction.

Liebreich[4] and Heidenhain[5], on the other hand, experimenting with a slightly different method, failed to get any evidence of the acidification of nerves in connection with functional activity.

Hermann, in the *résumé* of this subject given in his Handbook of Physiology (2, I, 139), gives his opinion that, while Funke's statement as to the irritative acidification of nerves has not been disproved, yet the phenomenon is of so delicate a nature that it can be detected only by the most sensitive reagents. The phenomenon must indeed be a delicate one since Ranke himself urges that the question should be decided by experiments on the spinal cord and should not depend upon the "doubtful results of tests applied to the nerve trunks." Now since the cord contains gray as well as white substance and as the gray substance, according to Ranke himself, becomes more acid than the white in functional activity it is clear that an acid reaction of the white substance of the spinal cord may depend upon an acid formed in the gray and passing by diffusion into the white substance. This possibility, which is indeed admitted by Ranke, seems to deprive the experiments on the spinal cord of what little value they possessed as evidence of the production of acid in connection with the activity of nerve fibres.

The other chemical changes which have occasionally been asserted to occur in active nerves rest on still weaker experimental evidence and it is therefore clear that chemical investigation gives us but little reason for maintaining a discharging in opposition to a kinetic theory of nerve action.

[2] Archiv. für Anat. und Physiologie, 1859, S. 835.
[3] Centralblatt f. d. med. Wiss. 1868, S. 769; 1869, S. 97.
[4] Tagebl. d. Naturf. Vers. zu Frankfurt 1867, S. 73.
[5] Studien IV, S. 248; Centralbl. f. d. med. Wiss. 1868, S. 833.

Heat Production.

The first experiments to test the heat production of active nerves were those of Helmholtz[6] who, after studying the analogous phenomenon in muscles, extended his investigations to nerve fibres. He failed, however, when all sources of error were carefully avoided, to obtain any evidence of heat production in connection with nervous activity, though his apparatus was capable of registering a change of temperature of 0.002° C.

Similar negative results were obtained by Heidenhain[7] who also experimented with the most delicate forms of thermo-electric apparatus.

On the other hand Valentin,[8] Oehl[9] and Schiff[10] maintain the affirmative side of the question, asserting that nerve fibres really are warmed by the passage of the nerve impulse. The statements of the latter observer are, however, rendered somewhat suspicious by the fact that he found the nerve fibre warmer at a point near than at one distant from the point irritated. This is explained by Schiff on the untenable hypothesis that the nerve impulse diminishes in intensity as it passes along the fibre.

In summing up the evidence on this question it is important to bear in mind that the methods of research employed by Helmholtz and Heidenhain were, to say the least, as accurate and as delicate as those of the other observers and we may, therefore, safely agree with Hermann (Handbook 2, I, 143) that the question whether a nerve produces heat on stimulation must be regarded as not yet settled, but if heat production does occur it must be exceedingly slight.

It seems, then, that the results of thermometric investigations speak no more positively than those of chemical research in favor of a discharging rather than a kinetic theory of nerve action.

Fatigue.

Without entering upon the question whether deficiency of decomposable organic material or accumulation of its products of decomposition is the essential chemical condition of fatigue, it will be sufficient for our purpose to consider what evidence there is that a nerve fibre, kept constantly stimulated, becomes less capable

6 Archiv. für Anat. und Physiologie, 1848, S. 158.
7 Studien IV, S. 250.
8 Moleschott Undersuch. IX, S. 2.5.
9 Gaz. Med. de Paris 1886, p. 225.
10 Pflüger's Archiv, IV, S. 230.

of performing its function, *i. e.*, of transmitting the impulse to the organs with which it is connected.

The evidence of the activity of a nerve may be either direct or indirect. The direct evidence consists in the occurrence of that change of the electrical condition known as the "negative variation" of Du Bois Reymond or the "action current" of Hermann. The latter writer quotes the former as authority for the statement that this phenomenon becomes less intense in successive repetitions of the experiment and regards this as evidence of the exhaustion of the nerve fibre. Unfortunately Hermann does not refer to the exact passage which contains this statement and an examination of the chapter on the negative variation of nerves in Du Bois Reymond's Untersuchungen fails to show any systematic study of the effects of fatigue on this phenomenon. Indeed, the method employed by Du Bois Reymond seems poorly adapted for such a study and the diminishing intensity of the negative variation noticed by this observer[11] may very possibly have depended upon causes not connected with the exhaustion of the nerve by its functional activity.

The indirect evidence of the activity of a nerve consists in the effect which it produces upon the central and peripheral organs with which it is connected. Of these effects the contraction of a muscle is the one which is most conveniently observed, but the fact that a muscle is more readily exhausted than a nerve renders it impossible to study the fatigue of nerves in this way without some special modification of the experiment.

Bernstein[12] was the first to employ the muscular contraction in experiments on the exhaustion of nerves. This observer applied a tetanic stimulation to the nerves of two nerve-muscle preparations through one of which, at a point on the nerve between the place stimulated and the muscle, a constant current of electricity was sent. The stimulus was thus prevented from reaching the muscle in one preparation while in the other its passage was unimpeded. While the latter muscle therefore was tetanically contracted, the former remained at rest. After the contracting muscle had become entirely exhausted, the constant current through the other preparation was opened and the muscle, which had been previously at rest, immediately contracted, thus

[11] Untersuchungen, II, 425. [12] Pflüger's Archiv, XV, 289.

showing that the nerve had not become exhausted by a stimulation which had lasted long enough to exhaust the muscle. To determine how long a stimulation was necessary in order to exhaust the nerve this method was not used because it was found that, after the prolonged passage of a constant current through the nerve, the opening of the current of itself caused a contraction (opening-tetanus) even without any stimulus applied above.

By a somewhat modified method, however, Bernstein reached the conclusion that a nerve may be exhausted by 5′–15′ tetanic stimulation.

The experiments of Bernstein have recently been repeated by Wedenskii[13] who, by using a feeble polarizing current and by frequently changing its direction, was able to avoid the opening tetanus which had led Bernstein to abandon this method of investigation. Experimenting in this way, Wedenskii was unable to find any evidence of the exhaustion of the nerve even after the tetanic stimulation had continued six hours. The opening of the constant current was invariably followed by a muscular contraction, which was proved to be due to the tetanic stimulation applied above by the fact that, when this stimulation was omitted, the opening of the constant current had no effect.

Another method of stopping the passage of the stimulus through the nerve to the muscle is by poisoning the animal with curare. In the case of an animal poisoned by this drug, a continued stimulation of a nerve should remain without effect upon the muscle connected with it as long as the animal continues under the influence of the poison, but as soon as the drug is sufficiently eliminated the muscle should begin to twitch. The use of the drug for this purpose was suggested by Wedenskii, but his experiments, which were made on frogs, do not seem to have been successful.

Their failure may well be supposed to depend upon the slow and uncertain manner in which curare is eliminated by these animals, and a study of the subject upon warm-blooded animals seeming desirable, experiments were made upon cats in the laboratory of the Harvard Medical School.[14] The animals were kept under the influence of a dose of curare just strong enough to prevent muscular contractions, while artificial respiration was maintained

[13] Centralblatt für die med. Wissenschaften, 1884, p. 65.
[14] Bowditch, Journal of Physiology, VI, 133.

and the sciatic nerve constantly subjected to stimulation sufficiently intense to produce in unpoisoned animals a tetanic contraction of the muscles. In this way it was found that stimulation of the nerve lasting from $1\frac{1}{2}$ to 4 hours (the muscle being prevented from contracting by curare) did not exhaust the nerve, since on the elimination of the curare the muscle began to contract.

It thus appears that evidence of fatigue in nerves resulting from functional activity is as difficult to obtain as that of chemical change or of heat production. A nerve isolated from the body for experimental purposes will of course gradually lose its irritability; but this change, which was observed by Du Bois Reymond, as above mentioned, seems to be associated with the gradual death of the nerve due to its altered surroundings rather than to physiological fatigue. It is conceivable that the *irritability* of a nerve should depend upon its possessing a certain definite chemical composition constantly maintained by metabolic changes and yet that the *irritation* of the nerve should produce no change whatever in its composition.

In support of this view an analogy may be drawn from the physiology of the muscular system. We find here that the power of the muscles to perform their function is intimately associated with the amount of nitrogenous material undergoing decomposition in the body but the performance of a given amount of muscular work, if within physiological limits, does not affect the amount of nitrogen excreted. In the case of muscles, to be sure, we have evidence of a considerable decomposition of non-nitrogenous material and also of heat production in connection with functional activity, but, if we limit our consideration to the nitrogenous element of muscular substance, the hypothesis above proposed for nerves finds its complete analogy in the muscular system.

The connection between nerves and muscles is so close that the muscular fibre has been described as "the contractile termination of the nerve." If the hypothesis here suggested be correct, we have a possible explanation of this close connection, for we may conceive that the vibratory impulse, after traversing the nerve fibre, continues its course through the muscular substance, producing in the nitrogenous portion of the muscle-molecule a kinetic change similar to, or identical with, that which occurs in the nerve, and, at the same time, setting up in the adjacent non-nitrogenous

portion, an explosive decomposition, the result of which is manifested as a muscular contraction.

Without, however, indulging in further speculation, let it suffice for the present to note the fact that investigations into the chemical changes, the heat production and the fatigue of active nerves all lead to results more favorable to a kinetic than to a discharging theory of nerve action.

We may, therefore, reasonably hope that future researches, if directed on this line, will throw further light on this most mysterious and interesting process.

PAPERS READ.

MEMORANDA OF A REVISION OF THE NORTH AMERICAN VIOLETS. By Prof. ASA GRAY, Cambridge, Mass.

IT seems most natural to throw all the Candollean groups into one, except the section *Melanium*, which includes the pansies, in this following the late M. Boissier; and to arrange our violets in six primary sections, upon characters of vegetation taken along with differences in the stigma. Thirty-three wild North American species are made out, of which only eight are represented in the Old World. There are one or two changes in nomenclature; but the only notable ones are in the second group, where *V. pedatifida* replaces the much later name of *V. delphinifolia*, and the Linnæan name of *V. palmata* asserts its right of priority over *V. cucullata* of Aiton. The species are thus arranged:

GROUP I. Strictly acaulescent; the dissected leaves and scapes all directly from an erect and short thick caudex rather than rootstock, never stoloniferous; corolla beardless; large antrorse-terminal stigma wholly beakless and naked.

V. pedata L., with var. *bicolor* Pursh, fide Raf.

GROUP II. Acaulescent; the leaves and scapes springing directly from the summit of a rootstock, or later more or less from runners; style with inflexed or truncate and beardless summit and an antrorsely beaked or short pointed small stigma.

* Rootstocks thick and short, multicipital, ascending or little creeping, never filiform nor stoloniferous, often fleshy-dentate; corolla only saccate-spurred, blue or violet, occasionally varying to white; at least lateral petals bearded. Species connected by transitions.

V. pedatifida Don. Syst. i, 320 (1831). *V. delphinifolia* Nutt. in Torr. & Gray, Fl. i, 136 (1838). This earlier name clearly belongs here and must be adopted. It is the *V. pinnata* of Richardson (not the Linnæan species, which has longer and narrower spurs), the *V. pedata* of Hooker's Flora as to the plant of Saskatchewan, etc. It has often been confounded with that species; but its affinities are with *V. palmata*, indeed is probably only a marked geographical variety of that species, with all the leaves finely dissected. It might take the much earlier name of *V. digitata* Pursh, except that Pursh founded it on a Virginian specimen, which he had seen in Major LeConte's herbarium. The latter, however, makes no mention of it in his monograph; but we suppose it to be his *V. septemloba*, the variety of *V. palmata* which comes nearest to the present species. Indeed, the late Professor Tuckerman long ago collected at Concord, Massachusetts, specimens which would surely pass for *V. pedatifida* if from the valley of the Mississippi.

V. palmata L. In the year 1856, in the second edition of my Manual, this was combined with *V. cucullata*, following the general conviction of our botanists; repeated studies during thirty years confirm the opinion. But *V. cucullata* Ait. ought to have been referred, as an entire-leaved variety, to the Linnæan *V. palmata*. I am the more constrained to do so now by the fact that the name *cucullata* would have to give way to the much earlier-published *V. obliqua* Hill, well figured and unmistakable in his Hortus Kewensis. To the various synonyms already adduced to the more or less cut-leaved forms of this multifarious and widely diffused species, I have only to add that of *V. digitata* Pursh, as suggested above.

Var. *cucullata*, the *V. cucullata* of Aiton (1789) and *V. obliqua* Hill (1769) with abundant synonymy, is characterized only negatively by the absence of cut leaves, and every one of its many forms is liable to have them, most so those which affect dry or sandy soil. Yet they have not been found at either the most northern or the farthest western limits of the species.

V. sagittata Ait. Generally well-marked as this is, yet it appears to be confluent on one hand into typical *V. palmata*, on the other into the var. *cucullata*.

* * Rootstalks thickish and creeping, stoloniferous, comparatively large-flowered; corolla blue or violet, with white varieties; lateral petals usually bearded; spur short and saccate; leaves cordate and merely crenulate.

V. Langsdorffii Fischer in DC. Arctic Alaska to Brit. Columbia, extending, I believe, to the Sierra Nevada in the state of Nevada. Quite distinct, as Maximowicz insists, from the more caulescent *V. mirabilis*.

V. odorata L., the Sweet Violet of the Old World, beginning to be naturalized.

* * * Rootstocks long and filiform (not thickened nor scaly except at base of old flowering growths), extensively creeping underground, sometimes in summer along the surface, in shade, leaf-mould, etc.

+ Corolla blue or purple, large-spurred, beardless.

V. Selkirkii Pursh, fide Goldie. Our identification of this northern species with *V. Kamtschatica* of Gingius in DC., and with *V. umbrosa* of Fries, appears to be confirmed. Few botanists are aware that *John Goldie*, the first describer of this marked species, and of several other Canadian plants, lived down to the present summer, dying at a great age, at Ayr, Ontario, June, 1886.

+ + Corolla blue or purple, short-spurred, smaller.

V. palustris L. In this country only alpine or subalpine, Labrador to Saskatchewan and Rocky Mountains, south to those of Colorado, and the higher parts of those of New England.

+ + + Corolla white, mostly with brown-purple lines on lower or also on lateral petals or a blotch, these bearded or beardless in the same species; spur short and saccate; stigma as if truncate and margined, antrorsely short-pointed. The three species run together.

V. blanda Willd. Geographical range fully as large as that of *V. palmata*. To this I refer two forms, which in their extremes would seem specifically distinct, viz.:

Var. *palustriformis*. Comparatively large, growing in shady or mossy and loose soil or leaf-mould, where it is freely and extensively stoloniferous; upper face of the leaves commonly hirsutulous in the way of *V. Selkirkii*, but less so; scapes often reddish; flowers rather larger; lower petal less lineate or picturate. This is *V. obliqua* Pursh (not Hill nor Ait.), and may also be his *V. clandestina* (in the summer state it is abundantly cleistogamous, and is the *V. amœna* of LeConte). It ranges from Canada to Delaware, and to the mountains of Utah, but passes freely into the ordinary type. In the dried specimens it so much resembles *V. palustris* that Sir Joseph Hooker not unnaturally referred the whole of *V. blanda* to that species.

Var. *renifolia*. *V. renifolia* Gray, Proc. Am. Acad, viii, 288, which seems quite different from the ordinary state of *V. blanda* by its round reniform and beneath soft-pubescent leaves, is so connected with the preceding variety that it can not be kept distinct. It also grows in wet mossy woods and swamps, from Nova Scotia to the district north of Lake Superior, and south to Massachusetts and central New York.

V. primulifolia L., including *V. acuta* Bigelow, in its various forms, as is well known, fills up the interval between *V. blanda* and *V. lanceolata*. It is an Atlantic coast species, except as to

Var. *occidentalis*. A form with ovate- or spatulate-oblong leaves, all tapering at base, coll. by T. Howell, much out of the ordinary range, at Waldo, S. Oregon, along streamlets.

V. lanceolata L. has a rather larger range, from Nova Scotia to Lake Superior, Florida, and Texas.

+ + + + Corolla yellow; lateral petals usually bearded.

V. rotundifolia Michx. Our only truly acaulescent yellow violet, well marked in its summer state by the unusually accrescent leaves lying flat on the ground. From the character and habitat this should be, in its cleistogamous-flowering summer state, the *V. clandestina* of Pursh.

Group III. Subcaulescent by leafy stolons, or caulescent, with ascending 2-3-leaved stems, slender, almost glabrous, multiplying by long filiform rootstocks; leaves all reniform or cordate, undivided; corolla a bright yellow, with saccate spur; stigma terminal, beardless and beakless.

V. sarmentosa Dougl. To this belongs *V. rotundifolia* Hook. in Lond. Jour. Bot. vi, 73, in Geyer's collection, a species which it considerably resembles at first, flowering direct from the rootstock.

V. biflora L. Always caulescent, no leafy stolons; stigma margined on two sides. In this country known only from the Colorado Rocky Mountains; in the Old World ranges from Kamtschatka and Japan to Europe.

Group IV. Subcaulescent, first flowering from the ground, on slender mostly subterranean shoots from a deep thick rootstock or caudex, not

stoloniferous nor creeping, later more caulescent, always low; corolla wholly or mainly yellow, except in last two species, the spur short-saccate; stigma beakless, sometimes with a short antrorse lip, concave, orbicular, antrorse-terminal or oblique at the large and gibbous clavate summit of the style, bearded below its margin by a tuft or rarely a ring of stiff and reflexed or spreading bristles. Western species, but one cismontane.

* Leaves undivided, from roundish-ovate or cordate to lanceolate; lateral petals slightly bearded or beardless in the same species.

+ Ovary and oval capsule glabrous.

V. pedunculata Torr. & Gray. California and Arizona.

V. Nuttallii Pursh. Kansas to the Saskatchewan, British Columbia, and the northern borders of California. Although some forms of this come near to the next, the capsule should distinguish them. A good part of Sir Wm. Hooker's *V. præmorsa* belongs here, namely the specimens of Scouler's collection. Also *V. linguæfolia* Nutt. in Torr. & Gray.

+ + Ovary and globular capsule pubescent.

V. præmorsa Dougl. in Lindl. Bot. Reg. t. 1254; Hook. Fl. as to pl. Dougl. only. *V. præmorsa* and *V. Nuttallii* Benth. Pl. Hartw. 298. This proves to be the species more commonly known as *V. aurea*, Kellogg, and a form of it must be his *V. Brooksii*. It ranges from W. Idaho and dryer parts of Washington Territory to Southern and Lower California, in a great variety of forms among them the var. *venosa* (*V. aurea*, var. *venosa* Watson, *V. purpurea* Kellogg); there are larger-leaved and long-petioled forms which approach *V. pedunculata*, and narrow-leaved ones which are very like *Nuttallii*.

* * Leaves finely dissected; subterranean shoots commonly sending up their scapiform peduncles from under ground; the last species more caulescent.

+ Petals beardless, essentially yellow.

V. Chrysantha Hook. Well marked by the bipinnately dissected leaves, beardless and deep orange-yellow petals, the upper slightly or largely brown-purple.

V. Sheltonii Torr. Known by the glabrous palmately dissected leaves of orbicular outline and light yellow petals. The stigma has the bearded tufts of the related species, but small.

+ + Lateral petals bearded; upper deep violet-purple or blue; lower pale or yellow.

V. Beckwithii Torr. & Gray is pubescent or puberulent, its rounded leaves palmately about thrice 3-parted into linear or spatulate-linear acutish or obtuse lobes, the primary divisions petiolulate; upper petals deep violet-purple, the others light blue or bluish, with yellow base, lateral ones short-bearded.

V. Halli Gray. Glabrous throughout; the leaves of ovate or oblong or irregular outline, subpinnately or pedately about twice parted into lanceolate or linear lobes, their tips obtuse or acutish and callous-apiculate;

veins or ribs indistinct; upper stipules commonly foliaceous, often enlarged and laciniate or entire; upper petals deep blue, others yellow or cream-color.—From Salem, Oregon, to Humboldt county, California.

V. trinervata Howell, in printed distribution, and in Botanical Gazette, viii, 207, as a questionable variety of *V. Beckwithii.* This is *V. chrysantha*, var. *glaberrima* Torr. in Wilkes' Exped., xvii, 238, where it is said (doubtless from Pickering's notes) that the upper petals are purplish and the others yellow. It is well distinguished from *V. Hallii* by the more pedately and less dissected leaves; the divisions from lanceolate to almost ovate, acute or apiculate, at maturity almost coriaceous, and *prominently 3-ribbed*, the lateral ribs intramarginal; also by the small and entire and nearly free stipules. It is known only in the eastern parts of Washington Territory, was rediscovered by Howell in 1874, and later by Suksdorf.

GROUP V. Caulescent; the few-several-leaved stems erect from short or creeping rootstocks; no stolons; no radical flowers; spur of corolla short and saccate; lareral petals commonly scantily papillose-bearded; stigma beakless, bearded or pubescent at the sides.

* Petals yellow; main stems usually naked at base and few-leaved above.

V. lobata Benth. Pl. Hartw. A species of the Pacific Coast, with very various and mostly digitately cleft or lobed leaves; with

Var. *integrifolia* Watson, with mostly deltoid- or rhombic-ovate often caudate-acuminate leaves, which is to the species what *V. hastata* is to *V. tripartita* Ell. Perhaps it passes to *V. glabella.*

V. hastata Michx., an Alleghany Mountain species, extending to Ohio and to the northwestern borders of Florida; generally well marked by its approximate and deltoid-hastate or subcordate leaves.

Var. *tripartita*, the *V. tripartita* Ell., a remarkable form with trifid or 3–parted or even trifoliolate leaves, evidently, as LeConte maintained, only an usual state of *V. hastata.*

V. glabella Nutt. in Torr. & Gray, Fl. A Pacific species, ranging from the middle parts of California to Alaska and to Japan; its northernmost forms coming too near the Asiatic *V. uniflora* L., while its most eastern in the northern Rocky Mountains are not readily distinguished from *V. pubescens.* With Maximowicz, I conclude that we should keep up these species.

V. pubescens Ait. This common and rather variable Atlantic American species, contrary to Maximowicz, I must keep entire. The capsule in all its forms varies from oblong to globular (even on the same stems), and from glabrous to densely tomentose; and the very pubescent plants are connected by transitions with

Var. *scabriuscula* Torr. & Gray, which should have been named *glabriuscula*, for it really is not scabrous.

* * Petals white, with violet or purple tinge, and some yellow or yellowish at base within; stems more leafy or more prolonged by successive

leaf- and flower-bearing growths up to midsummer; stipules small, narrow, entire and nearly scarious; capsule oval, glabrous.

V. Canadensis L. This ranges from Newfoundland to Saskatchewan and the Rocky Mountains, to those of Utah and Arizona. In New Mexico and Colorado it passes into

Var. *scopulorum*, a diminutive and depressed form, of which the most characteristic form was collected in Clear Creek cañon, by Mr. Greene.

V. ocellata Torr & Gray. Known only in California; seems well to hold its characters as a species.

V. cuneata Watson, Proc. Am. Acad. xiv, 290, and Bot. Calif. ii, 433. Mountain woods in the northern part of California and adjacent Oregon. Distinguished from the preceding by its smoothness and its rhombic-ovate or cuneate leaves, only the radical ones cordate.

GROUP VI. Caulescent from more or less creeping rootstocks, or at first flowering nearly acaulescent, erect or spreading; leaves cordate, undivided; stipules more or less herbaceous; corolla from blue to white, with *projecting* oblong to cylindrical spur; style moderately thickened upward, beardless.

* Spur of corolla not very long; lateral petals usually bearded; stigma inflexed, a short scarious beak. (*Caninæ.*)

+ Stipules from serrate to fimbriate-pinnatifid or pectinate.

V. striata Ait. Stems 3–4 angled, ascending and at length a foot or more long, producing normal petaliferous flowers until midsummer or later; corolla yellowish-white; lower petal striate with brown-purple lines; spur thick, rather shorter than the sepals; capsule ovoid.—An Atlantic and mostly northern species, extending along the mountains to Georgia, and westward only to Minnesota and Missouri. My *V. laciniosa* of Japan is the analogue of this rather than of any form of the next, with which Maximowicz would associate it.

V. canina L. Our forms of this collective species, none of them quite identical with European, may be grouped under the following varieties:

Var. *Muhlenbergii*, the common Atlantic American Dog Violet, nearest to the Old World *V. canina*, var. *sylvestris*, may as well retain the name under which Torrey published it (as *V. Muhlenbergii*) in 1824, the same year in which it was named *Muhlenbergiana* in the Prodromus. The alpine and arctic form of it, *V. Muhlenbergii*, var. *minor* Hook. Fl., has recently been illustrated under this name by Lange in the Flora Danica, from Greenland. Dr. Engelmann detected a summer form of it on the sand beaches of Lake Superior, answering to *V. arenaria*. Our plant is only spring-flowering; in summer it sends off prostrate stems bearing cleistogamous flowers.

Var. *multicaulis*, the *V. Muhlenbergii*, var. *multicaulis* Torr. & Gray, Fl., and doubtless *V. radicans* DC. (though the summer runners, so far as seen, do not root), is a peculiar form of the southern Atlantic States, in rocky or sandy ground, from Kentucky to Florida and Texas; there flow-

ering from February to April, depressed-spreading, and with round leaves; later in the season producing prostrate leafy branches or runners, bearing cleistogamous flowers.

Var. *adunca* Gray. To this, the type of which is *V. adunca* of Smith in Rees' Cyclopœdia, I refer all the far western forms of the species, which differ from the eastern somewhat in habit, in less cordate leaves, and in the generally longer spur which is disposed to be curved or hooked. The more southern and larger forms, which prevail in California, answer to *V. longipes* Nutt. The smaller and higher northern form answers to Regel's *V. canina*, var. *rupestris*.

Var. *oxyceras* Watson, in the Botany of California, is remarkable for its acute as well as long spur. It has been collected, so far as I know, only by Dr. Torrey, near Donner's Pass over the Sierra Nevada, and by Prof. Brewer and later by myself on very high ground between Clark's and the Yosemite.

+ + Stipules entire or nearly so, linear; flowers on scapes from the rootstock and few on 1-3-leaved ascending stems, pretty large.

V. mirabilis L. A species allied on one hand to *V. Langsdorfii*, on the other to *V. canina*, ranging from the mountains of Europe to N. E. Asia; and I somewhat doubtfully refer to it a plant collected in Oregon, near Portland, in coniferous woods, by Mr. Howell. The species was so named by Linnæus, because the only one he knew having what are now called cleistogamous flowers.

* * Spur to corolla very long; petals beardless; style slender-fusiform, symmetrical; stigma erect, and terminal, small; stipules laciniate-pectinate.

V. rostrata Muhl. A strongly marked species, of the Alleghany region, ranging from upper Canada and Michigan, through the higher parts of the state of New York, to the mountains of Georgia. Mr. Dolph long ago sent me, from northern Pennsylvania, flowers having the spur 2-3 corniculate at tip.

The section *Melanium*, which includes the pansy and *V. cornuta*, now well known but not so common in our gardens, and which has the enlarged and globular apex of the style hollowed into a large and deep nectariferous and stigmatic cavity, is represented in America only by

V. tricolor L., var. *arvensis* DC. I had always taken this field form of the pansy for a mere escape from cultivation; but it occurs in rather numerous localities from Canada to Texas; and several botanists familiar with it insist that it is indigenous.

If we count this as indigenous, in deference to the weight of authority, we have thirty-three wild species of violet in North America, all but eight of them endemic.

It is not out of place to remark that I persist in the opinion that *Solea concolor* of Gingius represents a genus quite distinct from *Ionidium*, and of course I should keep up *Hybanthus*.

THE DEVELOPMENT OF THE GYMNOSPORANGIA OF THE UNITED STATES. By Prof. W. G. FARLOW, Cambridge, Mass.

[ABSTRACT.]

THE paper gives the results of cultures of *Gymnosporangim clavipes*, *G. conicum*, *G. clavariæforme*, *G. macropus*, *G. globosum* and *G. Ellisii* for the purpose of ascertaining their aecidial condition. Specimens of the cultures will be shown with the paper. The following connections are supposed to be traced.

G. biseptatum with *Roestelia Botryapites*.
G. clavipes " *R. aurantiaca*.
G. Ellisii " *R. transformans* (?).
G. clavariæforme " *R. lacerata*.
G. conicum " *R. cornuta*.
G. macropus " *R. penicillata*.

A REVISION OF THE NORTH AMERICAN SPECIES OF THE GENUS FISSIDENS. By Prof. C. R. BARNES, Lafayette, Ind.

[ABSTRACT.]

THE present revision of the genus differs from the treatment in Lesquereux and James's Manual in the following points:

1. *F. inconstans*, *F. minutulus*, *F. exiguus*, *F. Texanus* } are referred to *F. incurvus*; *F. minutulus* and *F. exiguus* forming varieties of that species.
2. *F. crassipes* is dropped because no American specimens are known.
3. *F. Hallii* is allowed to stand as a very doubtful species, whose name must be changed to *F. Austini* should it hereafter prove to be a good species.
4. *F. ventricosus* is referred to the European *F. rufulus*.
5. The fruit of *F. grandifrons* is described.
6. The genus *Conomitrium* is reduced to *Fissidens*.

The paper presents descriptions of all the known North American species, twenty in number, together with complete synonymy and critical remarks. It includes also a key indicating the natural relationships of the species.

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SYNOPSIS OF NORTH AMERICAN PINES, BASED UPON LEAF ANATOMY. By Prof. JOHN M. COULTER and J. N. ROSE, Crawfordsville, Ind.

[ABSTRACT.]

AFTER giving an historical sketch and an account of the structure of the pine leaf, the following synopsis was presented:

§ 1. Fibro-vascular bundle one: ducts peripheral: leaves mostly in fives.

* A thin-walled layer next the epidermis: no strengthening cells next the epidermis nor about the ducts: leaves always in fives.

† Stomata on dorsal side of leaf.

1. *P. albicaulis.* 2. *P. flexilis.*

† † No stomata on dorsal side of leaf.

3. *P. reflexa.* 4. *P. Strobus.* 5. *P. Ayacahuite.* 6. *P. monticola.*

* * No thin-walled layer next the epidermis: strengthening cells next the epidermis and generally about the ducts: leaves one to five.

† Stomata on dorsal side of leaf.

7. *P. Lambertiana.* 8. *P. monophylla.* 9. *P. edulis.*

† † No stomata on dorsal side of leaf.

++ Dorsal side of leaf much broader than either ventral: cuticle not specially thickened: stomata not deeply set, the subsidiary cells even forming slight protuberances.

10. *P. cembroides.* 11 *P. latisquama.* 12. *P. Parryana.*

++ ++ Dorsal side of leaf as broad or narrower than either ventral: cuticle often much thickened and stomata very deeply set: leaves in fives

13. *P. Balfouriana.* 14. *P. aristata.*

§ 2. Fibro-vascular bundles two: ducts mostly parenchymatous or internal.

* Ducts parenchymatous (or peripheral in *P. resinosa*).

† Bundle-sheath thick-walled.

‡ A thin-walled layer next the epidermis.

= Leaves in pairs.

a. Strengthening cells about ducts, but none in the cortical region. Atlantic species.

15. *P. resinosa.*

b. Strengthening cells in the cortical region, but none about ducts. Pacific species.

16. *P. contorta.* 17. *P. muricata.*

= = Leaves usually in threes: ducts 2–10.

18. *P. Engelmanni.* 19. *P. Coulteri.* 20. *P. ponderosa.*

= = = Leaves in fives: ducts always 3, one in each angle.

21. *P. Arizonica.* 22. *P. Montezumæ.*

‡ ‡ No thin-walled layer next the epidermis: strengthening cells about ducts and in fibro-vascular region.

= Leaves in fives: stomata deeply set.

23. *P. Torreyana.*

= = Leaves in threes: stomata not deeply set.

24. *P. Jeffreyi.* 25. *P. Sabiniana.*

† † Bundle-sheath thin walled: a thin-walled layer next the epidermis.

‡ Strengthening cells in fibro-vascular region; few, if any, about ducts.

= Leaves in threes.

26. *P. Tæda.* 27. *P. serotina.* 28. *P. rigida.* 29. *P. insignis.*

= = Leaves in pairs.

30. *P. pungens.*

‡ ‡ No strengthening cells in fibro-vascular region, nor about the ducts.

= Leaves in threes.

81. *P. tuberculata.*

= = Leaves in pairs.

32. *P. inops.* 33. *P. clausa.* 34. *P. mitis.* 35. *P. glabra.* 36. *P. Banksiana.*

* * Ducts always internal: bundle-sheath thin-walled.

37. *P. palustris* (*australis*). 38. *P. Cubensis* (*Elliottii*).

THE BIOLOGY OF TIMBER TREES WITH SPECIAL REFERENCE TO THE REQUIREMENTS OF FORESTRY. By B. E. FERNOW, Dept. of Agriculture, Washington, D. C.

[ABSTRACT.]

IT is most necessary for forestry purposes to thoroughly understand the biology of the timber trees to be propagated, as injudicious methods of propagation, selection of unsuitable species and improper after-treatment may occasion heavy financial loss, the results being visible only after many years of investment.

The selection of the material for forestry purposes out of our 420 arborescent species is made difficult by the absence of knowledge as to the true value not only of the timber, but the growing capacities of our trees. Those species alone, which under given conditions will in the quickest and surest manner produce economic and financial results, require attention from the forester at first.

A classification may be made into dominant species, which are capable of forming extensive forests, coördinates, which may be occasionally grown in extensive plantations for their economic value, though properly not desirable for dominant forest growth, subordinates which are useful to fill up the forest stand.

Geographical distribution, centers of best development, habitat of species are influenced by general climatic conditions and by those of the site; the latter term comprising all the essential factors of wood production outside of climate, as altitude, configuration, exposure, soil conditions.

Under climate, discrimination between general and local climate is necessary, as local temperature, moisture, and movements of the air exert strong influence upon distribution and development.

The dependence of plant development on certain sum totals of insolation, the same for every species (thermic constants of vegetation) as demonstrated by H. Hoffmann, for tree growth probably will be modified by hygrometric conditions of the atmosphere, so as to make an independent consideration of one of these factors impossible.

The dependence of distribution on *temperatures* is apparent in vertical as well as horizontal distribution. Exposure has in this respect nearly the same significance as altitude, and liability of certain localities to spring and fall frosts also influence plant distribution.

Atmospheric moisture counteracts the effects of too rapid evaporation and transpiration. The diversity of different species in their demands on this factor of climate is probably due to the intensity of transpiration of which their leafage is capable. For wood production a very ample supply

of moisture is most beneficial, but for production of timber quality the requirements of different species vary greatly.

The almost absolute independence of timber production of the mineral composition of the soil is proved by the very small amount of ashes found in the wood; the usage of naming geological formations to describe suitable sites must therefore be discarded, as affording no indications either of chemical or physical soil conditions.

Capacity for moisture, looseness, depth and proper drainage of soil are determining conditions.

Configuration, nature of subsoil, exposure and nature of cover, besides the mechanical consistency, grain and depth of the soil influence the hydrologic conditions of the same. The intimate relation of soil humidity and wood growth indicates the necessity of studying root formation through all periods of the life of a tree. The various species show different powers of accommodation to degrees of moisture as well as to other conditions of site.

The most important points for the consideration of the forester, in which different timbers vary considerably, are the dependence of their development on the influence of light and shade and their rate of growth. A classification into shade-enduring and light-needing species in a gradual series is possible. The relative requirements as to light must be studied in the dense forest, where no side light changes the habit of forest growth. The capacity of trees to endure shade is manifested by the density of their foliage and by the tenacity in sustaining life of lower branches and overshadowed individuals.

Conditions of site modify the requirements for light. Alpine flora becomes light-needing flora; cloudy climes increase requirement of light and southern skies diminish it; so do humid atmospheres and fresh or moist soils.

As the preservation of soil humidity becomes a necessity all over the world, only such species, as are capable of shading the soil against undue evaporation should be chosen for the dominant forest. These are the shade-enduring ones.

A study of the *form development* must precede consideration of rates of growth. Trees may be classified according to their greater tendency to develop the bole or the crown. Their true habitus must be studied in the open; the dense forest influences the development especially of the latter class; it stimulates *height-growth*. Soil, situation and age influence form development, the energy of height-growth being increased in fresh and deep soils; while shallow and compact soils, altitude, cold winds, reduce this energy.

Energy and persistency of height-growth vary in different species and at different periods of life. The Conifers form the highest timbers and are the most persistent in development. Light-needing species grow quickly in their youth, but soon retard their rate. Density of forest stimulates especially the height-growth of those species which are inclined to subdivide and branch; *i. e.*, mostly deciduous trees.

Diameter development takes place in proportion to height-growth; light-needing species reaching their maximum rate early decrease in rate soonest. Shade-enduring timbers develop diameter later, but continue longer at a steady rate. The absolute diameter increase depends mainly on the capacity of the tree to utilize the available light; *i. e.*, on the crown development.

Mass accretion is a function of height and diameter development, but for entire forests the number of stems capable of being sustained on a given area enters into the calculation and consequently the shade-enduring species are the greatest mass producers.

If, in addition, the capacity of species for reproduction by seed and by division from root is considered, a large field for observation, measurements and deductions is laid out for the work of the forest botanist, upon the result of whose labor we must build our coming American forestry.

PLAN FOR LABORATORY WORK IN CHEMICAL BOTANY. By MISS LILLIE J. MARTIN, High School, Indianapolis, Ind.

[ABSTRACT.]

I. CHEMISTRY furnishes the means for investigating plants. The work of investigation falls into two divisions:—

1. The investigation of the composition of plants	Macro-chemical study Micro-chemical study
2. The investigation of the form of plants	Gross anatomy study Minute anatomy study

II. Plan for making an actual study of the composition of a plant. It combines macro- and micro-chemical work. It is laid out with the idea that the department of chemistry called the proximate analysis of plants really belongs to botany, that it should be relegated to it and be the foundation of all chemical botanical study.

(*a.*) Books that would be employed in carrying out the work laid down.

(*b.*) Best plants to select for students' work.

III. Plan for a laboratory desk for the course of study laid out above. A modified chemical laboratory desk so arranged as to hold not only the more important pieces of apparatus and reagents used in organic and inorganic chemistry, but also a microscope and other things that would be employed in micro-chemical work. A table for holding the microscope when in use is attached to the desk.

IV. An effort is made to show that if the course proposed is good in itself, neither cost nor time required, makes its adoption impracticable.

IMMUNITY FROM CONTAGIOUS DISEASES PRODUCED BY PRODUCTS OF BACTERIAL MULTIPLICATION. By D. E. SALMON, U. S. Department of Agriculture, Washington, D. C.

WHEN children have recovered from the measles they conclude that one of the troubles of life has been overcome, and no matter how much they

are exposed to that disease in the future, they rely upon their power to resist it without inconvenience. As a rule, their expectations are correct. The first attack has granted them an immunity from the effects of the contagion, which, while it is not absolute in every case, is certainly very remarkable. It is also a matter of the most common observation that other contagious fevers, to which people are subject, grant a similar immunity—a power to resist those particular forms of contagion for the remainder of the individual's life. The same is true of certain contagious fevers of other species of animals.

The nature of such acquired immunity has long been an interesting subject for speculation, and until comparatively recent times it has been mysterious and incomprehensible. Since the demonstration of the germ theory of disease, it became evident that there were three possible explanations of it.

1. Something had been deposited in the body during the attack of disease that was unfavorable to the specific germ.

2. Something had been exhausted which was essential to the development of this germ.

3. The living tissues had acquired such a tolerance for the germ or for a poison which it produces, that they are no longer affected by it.

If either the first or the third of these explanations were correct, it would appear possible that immunity might be granted by introducing into the tissues the liquids in which the specific germs had been cultivated and from which they had been removed by filtration, or in which they had been killed by suitable methods. I have long been convinced of the correctness of this supposition, but it is only recently that I have been able to make a satisfactory demonstration of the principle.

In these experiments I have used the virus of the contagious fever of hogs known as swine plague. This virus, cultivated in the laboratory in suitable liquids, is very destructive to pigeons when injected hypodermically in the region of the pectoral muscles, in doses of three-fourths of a cubic centimeter. To test the protective effect of the products of bacterial growth, the virus referred to was cultivated in a one per cent solution of peptone. After a number of days' cultivation, the culture was raised to 58° to 60°C., a temperature which soon kills the microbe; but to make sure that all life was destroyed, we invariably transferred a few drops of the heated liquid to a fresh tube of culture fluid. If any multiplication of the germs occurred, it was of course evident that the temperature had not been high enough or was not maintained for a sufficient time. This made it necessary to repeat the operation. As the thermal death point of the microbe had been carefully determined and as care was used to raise the temperature somewhat beyond this point it was seldom that any of the organisms remained alive. No liquid was used in these experiments, however, which had not been tested in this way and found free from living organisms. The necessary details will be found embodied in the following table:

TABLE SHOWING RESULTS OF EXPERIMENTS.

	Pigeons. No.	Sterilized Virus. 1st Dose. cc.	2nd Dose. cc.	3d Dose. cc.	4th Dose. cc.	Total cc.	Living Virus cc.	Results of Inoculations.
1st Experiment.	1	.4	1.5	1.5	1.5	4.9	.75	No effect.
	2	1.5	1.5	1.5	....	4.5	.75	" "
	3	1.5	1.5	1.5	....	4.5	.75	" "
	4	1.5	1.5	0.	....	3.	.75	" "
	5	.8	0.	....	....	.8	.75	Death in 48 hrs.
	6	0.	0.	....	....	0.	.75	Death in 24 hrs.
2d Experiment.	7	1.	1.	.75	....	2.75	.75	No effect.
	8	1.	1.	1.	....	3.	.75	" "
	9	1.	1.	1.	....	3.	.75	" "
	10	1.	1.	....	....	2.	.75	" "
	11	1.	1.	....	....	2.	.75	" "
	12	1.	1.	....	....	2.	.75	" "
	13	0.	0.	....	....	0.	.75	Death within 24 hrs.
	14	0.	0.	....	....	0.	.75	" " " "
	15	0.	0.	....	....	0.	.75	No effect.
3d Experiment.	16	1.	....	....	....	1.	1.	Death in 6 days.
	17	1.	....	....	....	1.	1.	Death in 16 days.
	18	1.	....	....	....	1.	1.	No effect.
	19	0.	....	....	....	0.	0.	" "
4th Exper't.	20	1. Evap. vir.	1. Evap. vir.	....	....	2.	.75	All slightly sick, and recovered.
	21	1. Evap. vir.	1. Evap. vir.	....	....	2.	.75	
	22	1. Evap. vir.	1. Evap. vir.	....	....	2.	.75	
	23	....	....	....	....		.75	

	Pigeons. No.	STERILIZED VIRUS. 1st Dose. cc.	2nd Dose. cc.	Total. cc.	Living Virus. cc.	Results of Inoculations.
5th Expert.	24	1.	1.	2.	.75	No effect.
	25	1.	1.	2.	.75	Slightly ill—recovered.
	26	1.	1.	2.	.75	No effect.
	27	0.	0.	0.	.75	Death in 5 days.
6th Expert.	28	1.	1.	2.	.75	Death in 7 days.
	29	1.	1.	2.	.75	Death in 11 days.
	30	1.	1.	2.	.75	No effect.
	31	0.	0.	0.	.75	" "
7th Expert.	32	1.	1.	2.	.75	" "
	33	1.	1.	2.	.75	" "
	34	.75	1.	1.75	.75	" "
	35	0.	0.	0.	.75	Death in 10 days.
8th Expert.	36	1.	1.	2.	.75	No effect.
	37	1.	1.	2.	.75	" "
	38	1.	1.	2.	.75	" "
	39	0.	0.	0.	.75	Death in 2 days.
9th Experiment.	40	1.5	1.5	3. } Evap.	.75	Death in 3 days.
	41	1.5	1.5	3. } Virus.	.75	No effect.
	42	1.	1.	2.	.75	" "
	43	1.	1.	2.	.75	" "
	44	0.	0.	0.	.75	Death in 1 day.
	45	0.	0.	0.	.75	Sick—recovered.

RÉSUMÉ OF EXPERIMENTS.

		DIED.		SICK.		NOT AFFECTED.	
	No. inoculated.	No.	Per Cent.	No.	No.	Per Cent.	Per cent.
Protected with more than 1cc. sterilized virus.	29	3	10.3	4	13.8	22	75.9
Not protected.	15	10	66.7	2	13.3	3	20

Of the nine experiments included in the table, five, viz., the first, second, fifth, seventh and eighth, give very positive results. In these twenty-seven pigeons were used. Of the nineteen protected pigeons, not one died from inoculation and eighteen had acquired perfect immunity; while of the eight unprotected pigeons, which were used as checks, seven died and but one resisted. The ninth experiment is almost equally positive. In this case, the virus used for two birds was evaporated over a water bath, to learn if a boiling temperature destroys the protective power. One of the pigeons so treated did not gain immunity.

The negative results of the other experiments was partly due to changing the conditions in order to learn those which were favorable and unfavorable to the production of the desired effect.

THE THEORY OF IMMUNITY FROM CONTAGIOUS DISEASES. By D. E. SALMON, U. S. Department of Agriculture, Washington, D. C.

THE immunity which an individual acquires from the effects of a contagion, by passing through one attack of the disease which it causes, has never been completely and satisfactorily explained. Various conjectures have been offered but no one of these to my knowledge has been based upon sufficient direct and positive evidence to warrant its acceptance as a well established theory of immunity. Since the demonstration of the germ theory of contagion it has been evident that there were, in a general way, three possible explanations of acquired immunity, viz.: A substance might be formed in the body during the course of the disease which is unfavorable to the multiplication of the microbes; or a substance essential to the growth of these microbes might be excreted or in some way lost or destroyed during this period; or, finally, the living matter of the body might acquire the power to resist or prevent the growth of the microbes.

It is well known that Pasteur has adopted the second or exhaustion theory and sustains it by his observations on the growth of microbes in culture liquids contained in flasks. If we sow chicken bouillon, he says, with the microbe of fowl cholera and after three or four days filter the liquid in order to remove all traces of the microbe, and afterwards sow this parasite again in the filtered liquid, it will be found powerless to resume the most feeble development. He assumes that there are but two hypotheses by which this fact can be explained. Either the microbe has exhausted something from the culture liquid essential to its multiplication, or it has added some substance which is unfavorable to it. To decide between these two possibilities a culture of the microbe was evaporated *in vacuo*, without heat, and then brought back to its original volume by the addition of fresh culture liquid. He reasoned that if the growth of the microbe had been arrested in the culture by the formation of a substance which acted

as a poison upon it, then the activity of the microbe would not be renewed after the addition of the fresh liquid since the volume had not been increased and all of the chemical principles were retained. As a matter of fact the multiplication of the microbe was renewed, and consequently the antidote theory was rejected and the exhaustion theory adopted.

Doubtless M. Pasteur's conclusion is correct as applied to the growth of microbes in flasks, but when we take into consideration the conditions under which such organisms multiply in the animal body, we find the elements of the problem very materially changed. The body is very different from a culture flask to which nothing gains entrance and from which nothing is eliminated. The insusceptible fowl is continually taking into its system fresh food which contains principles suited to the growth of the microbe in question. If the body is to be compared to a culture flask we should expect the immunity to be, at the most, of but a few days' duration, since the fresh nutriment should increase the capacity for growth in the one as well as in the other. Immunity from contagious diseases, when once acquired, however, does not terminate so soon and generally persists for years.

The exhaustion theory is susceptible of being tested by direct experiment. If a fowl is insusceptible to cholera because it lacks some element essential to the growth of the microbe, then bouillon made by infusing the muscles of this fowl in distilled water should also lack this same element and would therefore be equally incapable of nourishing the germ. In February, 1881, the writer was investigating the subject of fowl cholera and made this experiment; and he found that the proliferation of the microbe was just as vigorous in bouillon made from insusceptible fowls as in that made from susceptible ones. (Rep. U. S. Dep. Agric. 1881 and 1882, p. 292).

Both the antidote and the exhaustion theory, consequently, fail when tested by direct experiment; indeed when we consider that there must be a different chemical substance exhausted from the body for each contagious disease against which immunity is acquired in the one case, or a different product for each disease added in the other case, the theories become at once improbable.

If we direct our attention now to the third or vital resistance theory such discrepancies in regard to well-established facts will not be found. Immunity is probably never absolute but simply relative. Chauveau found that the Algerian sheep supposed to be insusceptible to charbon would succumb to that disease if a sufficiently large dose of virus was administered, and the writer found that fowls insusceptible to ordinary doses of cholera virus would contract the disease if the dose was sufficiently increased (*loc. cit.* p. 289). By turning these experiments in the opposite direction I found that the effect of virus upon susceptible fowls varied to a certain extent with the dose, and a point was finally reached at which no symptoms of disease were produced although some of the most virulent germs were introduced into the body. (Rep. U. S. Dep. Ag. 1883, p. 48).

These facts indicate that the tissues of the most susceptible individuals are not suited to the growth of microbes when the functions of the cells are normally performed; because, if favorable, one germ introduced into the interior of the body would multiply just as it does in a culture flask and finally produce the disease with the same certainty as would a million. This not being the case, it is evident that by increasing the dose the resistance of the tissues is in some way overcome, the microbes multiply and the disease is produced. If the germs failed to multiply, when a small number were introduced, because there was something lacking in the constituents of the body which is essential to their growth, it is difficult to understand how this unfavorable condition can be overcome by increasing the dose of virus; or if the failure to multiply was due to the existence of some substance which acts as a poison to the microbe, it is equally difficult to conceive how a large dose of virus would ensure proliferation where a small one fails.

That the influence which prevents the multiplication of the microbes is connected with the vital activity becomes more probable from the fact that the bacteria of putrefaction, organisms closely related to the pathogenic microbes, are unable to reproduce themselves when introduced into the tissues; but they find favorable conditions for growth there as soon as the life of the tissue is destroyed.

Admitting for the moment that immunity is due to the vital processes producing conditions which are unfavorable to the microbes of disease and the questions at once arise, What is this unfavorable condition? and How do the living cells act upon the lifeless liquids of the body to prevent the development of microbes which may be floating in these liquids?

To answer this difficult question, the writer, in 1882, advanced the theory that when the living matter of the body was in a condition of normal activity it kept the free oxygen so completely removed from the liquid as to prevent the multiplication of such organisms as are dependent upon a supply of free oxygen. Since then Metschnikoff has propounded a theory that there is a struggle for existence between the wandering cells of the body, which he calls phagocytes, and the bacteria. If the latter are in small number they are ingested and destroyed by the phagocytes, but if their number is relatively large they overcome the phagocytes and continue their development until disease results.

We have not sufficient facts up to this time, to enable us to make a definite choice between these theories. Microscopical investigations of the liquids of animals affected with contagious diseases indicate that microbes may exist in these liquids, and neither be ingested by phagocytes nor yet multiply with anything like the rapidity that they do when the vital influence is removed. Chauveau, in an attempt to learn what become of the *Bacillus anthracis* when injected in large doses into the blood-vessels of insusceptible sheep, found that the organism did not multiply but that it might still be found in the blood clots of the heart, and in the capillaries from twelve to forty-six hours afterwards. This indicates, I might say

it proves, that there is some other influence which prevents the multiplication of pathogenic germs in such cases besides their ingestion by phagocytes.

Another question which suggests itself is, How do the microbes overcome the unfavorable conditions to their development which normally exist in the animal body? There are a number of facts bearing upon this aspect of our problem. Zuelzer and Riemschneider found that cultivated bacteria which might be introduced under the skin and into the circulation of different animals without producing septic accidents, would produce these effects if two to five centigrams of neutral sulphate of atropia were added to the liquid injected. This shows that a narcotic may enable otherwise harmless bacteria to multiply in the tissues.

It has been demonstrated that putrefying animal substances, such as pus, blood, and water in which flesh has been macerated, acquire at times the most virulent properties, and a small quantity is even sufficient to destroy a horse. Chauveau has shown that when such liquids are filtered, the filtrates, though eminently poisonous, did not produce local effects, but that this filtrate injected with the bacteria enabled them to produce effects incomparably greater than when the organisms were mixed with water alone. Hiller went a step beyond this and found in his experiments that if such bacteria were filtered from the poisonous liquids and thoroughly washed with water so as to free them entirely from the poison adhering to them, they might then be injected into dogs, rabbits, and frogs without producing any effect.

From these facts we conclude that certain bacteria are pathogenic because they produce during their growth in albuminous liquids extremely virulent poisons, probably of a narcotic nature which depress the vital functions or entirely arrest them at the point where the microbes gain entrance into the body, and by this means they are enabled to propagate themselves.

Do the microbes of the contagious fevers produce such poisonous substances during their multiplication? Pasteur has shown that the fowl cholera microbe produces a narcotic when grown in culture liquids, which when separated from the organisms and injected in sufficient quantity produced symptoms identical with those of fowl cholera, but which symptoms disappeared in the course of a few hours. The writer repeated this experiment, confirmed the conclusion and found that the poison when very concentrated entirely destroyed the life of the tissues.

In the investigations of swine plague which have been made by the Bureau of Animal Industry, it has been discovered that the microbe of this disease also produces a poisonous principle which was tested upon the circulation of small animals by Dr. Beyer and found to produce effects almost identical with those caused by atropia.

With these observations before us, we can readily understand how a relatively large dose of virus overwhelms the animal cells at the point of its introduction with its peculiar poison, arrests their activity, prevents them from withdrawing the oxygen, at least to the normal degree, from

the liquids surrounding them, and in this way overcomes those conditions which are unfavorable to the growth of the microbes. This view is confirmed by the recent investigations of Ehrlich who shows that the living tissues have such an affinity for oxygen that they keep it completely removed from the liquids surrounding them; also by the observations of Bernard and Bert, who have found that when the vital activities are depressed by various causes, oxygen accumulates in the liquids of the body.

With these various facts in mind, we are prepared to understand how immunity results from one attack of a contagious disease. The cells of the body are at first depressed in their activity or narcotized by the poison of the microbes, but after being subjected to its influence for a certain length of time they acquire a tolerance for it; just as people acquire a tolerance for tobacco and are able to smoke and chew it without inconvenience, although the first attempt made them deathly sick. Of course, as this tolerance is gained, the tissues resume their vital functions as before, the liquids of the body become unfavorable to the existence of the microbe and it perishes. From that time forward for a considerable, though indefinite and variable period, the animal enjoys an immunity from that particular microbe when introduced in limited doses; but just as almost any one can be made sick by sufficiently increasing the dose of tobacco, so the immunity of most individuals may be overcome by administering a very large dose of virus.

If these conclusions are correct, then, we should be able to develop immunity by introducing into the body the poisonous products of bacterial growth which have been freed from all living organisms. This result would be a most decided advance in the preventive treatment of contagious diseases. Investigations of this question have not been as numerous or thorough as is desirable. Pasteur found that his fowls which had been treated with the narcotic above referred to were still susceptible. The writer made many experiments with the same poison, which were also negative in their results. Law has published experiments with swine plague from which he claims positive results, but the number of animals operated upon is too limited to be at all conclusive, even if the details of the experiments were satisfactory, which is not the case. Quite recently in our experiments, pigeons have been granted a very complete immunity from the effects of swine plague virus by treating them with cultures of the microbe, in which all living organisms had been previously destroyed by heat. Up to this time, however, our experiments with pigs have only given negative results.

Although there are still some points in connection with this subject which greatly need experimental elucidation, it is believed that the theory developed in this paper is in accordance with the facts so far demonstrated. The problems of immunity have long been considered impenetrable mysteries, and if this theory does not prove in all respects correct, it is hoped that it may, at least, be of some service to other investigators.

A POINT OF PRIORITY IN REGARD TO THE THEORY OF IMMUNITY FROM CONTAGIOUS DISEASES. By D. E. SALMON, U. S. Department of Agriculture, Washington, D. C.

[ABSTRACT.]

DR. STERNBERG claims priority for having originated the vital resistance theory of immunity. Dr. Law claims to have reached the same conclusion independently and at the same time, and to have demonstrated that immunity might be produced with sterilized virus.

This paper shows that the theory under consideration was offered several years before the time claimed by either of these gentlemen. Also that Law's demonstration was unsatisfactory, that his experiments repeated by the writer do not sustain his claims and that it is not probable that immunity can be granted under the conditions of his experiments.

THE VARIABILITY OF PATHOGENIC ORGANISMS AS ILLUSTRATED BY THE BACTERIUM OF SWINE-PLAGUE. By THEOBALD SMITH, M.D., Washington, D. C.

[ABSTRACT.]

BY inoculation into mice, a bacterium was isolated from one of a number of spleens taken from swine-plague in Nebraska, which resembles the bacterium of swine-plague found in the East, in regard to its morphological and pathogenic characters, and yet differs from it in certain minor biological features, that it seems justifiable to regard one as a variety of the other, or both varieties of a third form.

This new bacterium resembles the bacterium of swine-plague in form, size and mode of staining. Like the former it is motile when cultivated in liquid media and fails to liquefy gelatine. Both grow alike on agar-agar and potato, and both fail to affect the microscopic appearance of milk in which they multiply. The thermal death-point of both is about 58° C. Cultures of various ages are killed by an exposure to this temperature for fifteen to twenty minutes. In neither is there any indication of spore formation. Both produce the same lesions in mice, rabbits and pigeons after the subcutaneous injection of pure cultures.

This bacterium differed from the bacterium of swine-plague in the following minor but constant features: 1. In liquid cultures of the former the surface was covered by a complete membrane within one or two days which is invariably absent in cultures of the latter but may occasionally appear in advanced, old cultures. 2. It is more sensitive to the reaction of the culture media, as it failed to grow in neutral gelatine but grew vigorously in such as was slightly alkaline, while the other bacterium grew in both, but more vigorously in the alkaline medium. 3. This microbe failed to induce the disease in guinea-pigs.

The study of these two closely related microbes presents the first evidence as to the possibility of the variation of pathogenic forms. It raises a number of questions as to the causes of variation whether dependent on external conditions, such as climate, soil, etc., or upon the organization of the susceptible animals which in turn depends upon their food, mode of life, race, etc.

These facts suggest the possibility of the variation of other pathogenic microbes and may offer an explanation of the varying virulence of epidemics of the same disease at different times and in different localities.

THE BACTERIUM OF SWINE PLAGUE. By D. E. SALMON and THEOBALD SMITH, U. S. Department of Agriculture, Washington, D. C.

[ABSTRACT.]

A SHORT account of the morphology and physiology of the bacterium, its growth in different media and the animals which are affected by it. The characters are pointed out by which it may be distinguished from other organisms.

ON SOME CONTAGIOUS DISEASES OF INSECTS. By Prof. S. A. FORBES, Champaign, Ill.

[ABSTRACT.]

CONTAGIOUS insect diseases are first classed according to their organic causes (Hyphomycoses, Shizomycoses, Sperozoses, etc.), and then according to their capacity of hereditary transference. A germ disease of the larva of *Pieris rapæ* L., is described at length, as to its symptoms, course and histological characters, and its bacterial character is demonstrated. Fluid and solid cultures of the bacteria are described, and the conveyance of the disease to larvæ of *Pyramei cardui* L., by means of fluid cultures from the cabbage worm is shown by description of the experiment and its results.

The only partially successful result is then given of some experiments for the transference of pibrine of the silkworm to other insects, a study of "jaundice" of the silkworm is reported, with similar transfer experiments, illustrated by numerous cultures, and brief mention is made of a disease of the larva of *Nephelodes violans*.

The paper is illustrated by numerous microscope slides and solid cultures, and photographs of both.

Do any of our North American bats migrate? Evidence in the affirmative. By C. Hart Merriam, M.D., Washington, D. C.

[ABSTRACT.]

It is not ordinarily believed that bats migrate, the prevalent notion being that they spend the winter in a dormant condition in caves, hollow trees and other places of retreat.

In the case of two species, namely, the hoary bat (*Atalapha cinerea*) and the silver-haired bat (*Vesperugo noctivagans*), evidence of migration is complete.

The hoary bat belongs to the *Canadian fauna*, but, in fall and winter, occurs at places far to the southward of its breeding range. The silver-haired bat occurs regularly in spring and fall at a lonely rock about thirty miles off the coast of Maine. No bats breed at this place, and the nearest island is fourteen miles distant.

The lampreys of Cayuga lake. By Simon H. Gage, Ithaca, N. Y., and Seth E. Meek, New York, N. Y.

[ABSTRACT.]

The points brought out in this paper are:

1. The determination of the specific identity of the large Cayuga lake lamprey and the sea lamprey.

2. The discovery of *Ammocœtes branchialis* east of the Mississippi valley.

3. The determination of the constant presence of a dorsal fold or ridge in the males and of a ventral fin-like fold in the females of *Petromyzon marinus* at the breeding season.

4. The nests are excavations in the bed of the stream, usually just above ripples. In the fine sand and gravel, at the bottom of these nests, the eggs are laid and the embryos developed. The pile of stones at the lower edge of the excavation is not the nest as is often supposed.

5. The breeding season lasts nearly two months (May and June), and a single nest may be used by successive pairs of lampreys.

6. The larvæ, or immature forms, live in the sand along the edge of the stream just below the water line.

VASO-MOTOR NERVES OF THE LIMBS. By Dr. H. P. BOWDITCH, Harvard Medical School, Boston, Mass.

[ABSTRACT.]

IN most of the recent experiments on the vaso-motor nerves of the limbs, the temperature of the skin has been taken as the index of vaso-motor activity. It is evident, however, that by this method transitory changes cannot be recorded and quantitative results cannot be obtained. In experiments made with the plethysmographic method, to which these objections do not apply, it was found that either a constriction, or a constriction followed by a dilatation, or a dilatation of the vessels of the leg, may be produced by an electric stimulation of the sciatic nerve. The character of the result depends largely upon the strength and rapidity of the induction shocks used as a stimulus. In the following table are given the results of 909 observations of the effect of stimulations of the sciatic nerve with induction shocks of varying intensity and rate.

Rate of Stimulation.	WEAK.				MEDIUM.				STRONG.			
	No. of Obs.	Per cent			No. of Obs.	Per cent			No. of Obs.	Per cent		
		—	— +	+		—	— +	+		—	— +	+
0-4 in 1"	108	9.3	57.4	33.3	218	7.8	69.7	22.5	142	6.3	69.7	23.9
5-16 in 1"	69	31.9	60.9	7.2	153	28.8	58.8	12.4	109	5.5	89.9	4.6
30-64 in 1"	62	48.4	50 0	1.6	40	50.0	50.0	0.	8	37.5	62.5	0.

The figures in the columns headed —, — + and + show in what per cent of the total number of observations the effect of the stimulation of each rate and strength was respectively a constriction, a constriction followed by a dilatation and a dilatation. It will be observed: 1. That with each rate and intensity of stimulation the result, in at least one-half of the observations, is a constriction followed by a dilatation; 2. That with an increasing rate of stimulation the proportion of cases giving a simple dilatation diminishes while (except with strong stimulations) that of cases giving a simple constriction increases.

With slow irritations it was found that dilatations are more readily produced with feeble than with strong irritations. Experiments with animals whose nerves had been cut several days previously showed that degeneration of the nerve causes the loss of its constricting earlier than that of its dilating power.

It thus appears that the sciatic nerve contains fibres which both contract and dilate the vessels; but the former effect being more prompt than the latter, both in its appearance and disappearance, the two effects never neutralize each other.

A fresh nerve with a strong and rapid stimulation are the best conditions for producing constriction. A degenerated nerve with a feeble and slow stimulation are the best conditions for producing dilatation.

THE FACIAL NERVE IN THE DOMESTIC CAT. By T. B. STOWELL, Ph.D., Cortland, N. Y.

[ABSTRACT.]

THIS contribution to comparative neurology is offered with the desire to place the neurology of the domestic cat on a comparable basis with the osteology and the myology of the same mammal, which have already been published. The anatomy of the brain has been described by Dr. B. G. Wilder. The origin and the distribution of the cranial nerves have not, to my knowledge, been given. The vagus nerve was described by me in the Proceedings of the American Philosophical Society, July, 1881, and a paper upon the trigeminus nerve was read before the same society May, 1886.

The facial nerve may be traced to the cerebellum with the medi-peduncle and the prepeduncle, to the epicoele, and to the caudal region of the metacoele. Its ectal origin is from the latero-cephalic border of the trapezium, meso-cephalad of the auditory nerve. The ento-cranial trunk receives an accession (apparently from the auditory) just peripherad of the arteriole which separates the facial and auditory nerves at their ectal origins. Is this Wrisbery's intermediary nerve, and Sapolini's thirteenth cranial nerve? The interosseous portion traverses the serpentine flexions of the fallopian aqueduct to the stylo-mastoid foramen. At the angle in the aqueduct about 3 mm. peripherad of the ental meatus auditorius a considerable ramus about 2 mm. in length is given off which divides into four ramuli: these constitute the mesal root of the great superficial petrosal nerve, the small superficial petrosal nerve, a ramulus to the sympathic plexus, and a ramulus to the eminence upon the caudo-lateral angle of the Gasserian ganglion.

From the interosseous portion the tympanic nerve is given to the stapedius muscle. At the geniculate ganglion it communicates with the petrosal ganglion of the glossopharyngeal, with the jugular ganglion of the vagus nerve, and with the chorda tympani.

The principal communicating branches of the ecto-cranial nerve relate the facial with the superficial cervical, the mental, the buccal, the auriculo-temporal, the supra orbital, the great auricular (spinal) and the small auricular (spinal) nerves. The principal ecto-cranial divisions are the digastric, the stylo-hyoid, the cervico-facial, the temporo-facial and the auricular nerves.

The anatomical relations of this nerve are such as to justify the dissection of the cat as a preliminary to anthropotomy, and to determine physiological functions.

(The entire paper will be published in the Proceedings of the American Philosophical Society for 1885.)

RELATIVE STABILITY OF ORGANS AS DEPENDENT ON PHYLOGENY. By Dr. FRANK BAKER, Washington, D. C.

[ABSTRACT.]

A NUMBER of instances are cited to show that the longer a structure has been actively employed phylogenetically, the more stable is its function and the less likely to be interfered with by pathological processes.

ON AREAS OF FORM AND COLOR-PERCEPTION IN THE HUMAN RETINA. By Prof. J. H. PILLSBURY, Northampton, Mass.

[ABSTRACT.]

AFTER describing the methods of observation and apparatus used, the paper discusses the following points:

1. Relation between myopia of the eye and the extent of the area of form vision.
2. Relative extent of areas of form- and color-perception.
3. Relative extent of areas of color-perception for different colors.
4. Some curious irregularities of areas of color perception.

DEMONSTRATION OF AN EASY METHOD OF MEASURING REACTION TIMES. By JOSEPH JASTROW, Ph.D., Philadelphia, Pa.

[ABSTRACT.]

As several good text-books of physiology devote a page or two to the subject of the time taken up by the processes involved in a reflex and voluntary action and sensation, as well as the simpler mental processes, it will perhaps be of use to instructors in physiology, to be provided with a simple and inexpensive method of demonstrating the main facts in this interesting subject.

I. *Simple reaction times.* A number of persons arrange themselves in a circle, each with his finger resting upon the shoulder of the one before him. At a given signal he presses his neighbor's shoulder who, upon receiving the impression, transfers it to his neighbor, and so on. The time (which in all the experiments is taken by counting the ticks of an alarm-clock beating quarter-seconds) consumed by the operation, divided by the product of the number of persons into the number of revolutions, will give the average reaction-time for a touch impression.

II. *Distinction Time.* Let the distinction be between two sensations.

Take a pack of playing cards, throw out the face cards and shuffle the remaining forty cards. Hold them with the backs towards yourself and at a given signal by the assistant (who will act as time-keeper) turn over and place on the table the first of the forty cards, and dispose of the rest of the pack in the same way as rapidly as possible. Next, do the same, but do not deposit the card before you have distinguished whether its markings were red or black. The difference in time between the two operations, divided by forty, will give the average distinction time. The process can be complicated by making several distinctions with many packs of cards, etc.

III. *Choice Time.* Again take the simplest case, a choice between two modes of reaction. Throw the cards (face towards you) as rapidly as possible, into two packs without any definite order of distribution. Next, place all the red cards on one pack and all the black on the other. The difference in time between these operations (divided by forty) will be the time necessary to tell the color of the card plus the time necessary to choose the right pack upon which it is to be placed. We know the former time from II; subtraction gives the latter. Many complications can be introduced.

IV. *Association Time.* Three persons, A, B and C, are needed. A calls off from a prepared slip one of ten short concrete nouns to B, who, as soon as possible after hearing each call-word, names a word associated in any way with it, whereupon A calls the next and so on through the list; while C records the time. Next B does the "calling" and A the "associating." Then A and B each have a list of ten words, and simply call the words alternately as soon as heard. By having the three subjects in turn play the part of "caller," "associater" and "time-keeper," we get the values of six equations: viz., A (caller) + B (assoc.) = ?; B (caller) + A (assoc.) = ?; A (caller) + C (assoc.) = ?; C (caller) + A (assoc.) = ?; B (caller) + C (assoc.) = ?; C (caller) + B (assoc.) = ?; whence a simple algebraic solution yields the value of the time of each.

The principle underlying the method is that of having a *series* of reaction-time to measure, and thus dispensing with elaborate time-recording apparatus; and in case of II and III that of having the subject himself produce the sensation upon which he is to react.

[For a more complete account one is referred to "*Science*," Aug. 20, 1886.]

THE DREAMS OF THE BLIND AND THE CENTRES OF SIGHT. By JOSEPH JASTROW, Ph.D., Philadelphia, Pa.

[ABSTRACT.]

ONLY the more important physiological points in a more extended psychological study of the dreams of the blind will be here noticed. The fact that man is a "visual" animal, that sight is his most important sense, comes to light in such a saying as "seeing is believing." The great activity of

sight in waking life is continued in sleep and gives rise to "visions;" the most frequent and characteristic presentation of dreams. To the blind all this is impossible and their store of picture memories must be founded on another series of sensations, especially of hearing, and to a less extent of touch. From a physiological point of view, the fact of dream-vision would mean that in the dreamer's brain there is developed a sight-centre, the spontaneous activity of which is the material substratum of his dreams. Brain centres, we know from observation and experiments on animals, are of slow growth. By asking what is the latest age at which a child may become totally blind and still retain dream-vision, we shall be asking, "How long a time is necessary for the sight centre to develop sufficiently to enable it to function without further retinal stimulation. Two hundred blind persons (mostly young) in the Institutions for the Blind at Baltimore and Philadelphia were questioned in detail with regard to their dreams; and from their answers I conclude that the critical age is between the fifth and the seventh year. Those losing their sight before this age have no more vision in their dreams, than if they were blind from birth; those who become blind during this period, may or may not lose dream-vision (depending probably on individual development); while those, whose eyesight is destroyed after this period, find themselves quite on a par with seeing persons in dream life. This conclusion agrees with that of Dr. Heerman, whose paper was published in Ammon's Zeitschrift for 1838. In my case, however, only cases of total blindness are employed as a basis for this conclusion. With regard to cases of partial blindness, it is found that the same period divides those whose dream-vision is brighter and more vivid than the partial sight of waking life, from those whose waking life furnishes, though filled with imperfect sensations of sight, the material for dream images. Further points of interest are that, after many years, the dream pictures tend to lose their original vividness; that the blind dream quite as frequently as normal people; and that the critical period from the fifth to the seventh year corresponds with what many authorities regard as the extreme age at which loss of hearing will cause deaf-mutism and with the age at which one begins to remember sufficiently of one's self to mark it as the beginning of one's personal consciousness.

ATAVISM THE RESULT OF CROSS-BREEDING LETTUCE. By Dr. E. LEWIS STURTEVANT, Geneva, N. Y.

THE BULLIFORM OR HYGROSCOPIC CELLS OF GRASSES AND SEDGES COMPARED. By Prof. W. J. BEAL, Agricultural College, Ingham Co., Mich.

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ON THE DEVELOPMENT OF THE HUMAN CHORION. By Dr. CHARLES S. MINOT, Boston, Mass.

SECTION H.

ANTHROPOLOGY.

ADDRESS

BY

HORATIO HALE,

VICE PRESIDENT, SECTION H.

THE ORIGIN OF LANGUAGES, AND THE ANTIQUITY OF SPEAKING MAN.

In the study of every science there arise from time to time difficult questions or problems, which seem to bar the way of the student in one direction or another. It becomes apparent that on the proper solution of these problems the progress of the science mainly depends; and the minds of all inquirers are bent earnestly on the discovery of this solution. Such in biology are the questions of the origin of life and the genesis of species. Anthropology, and its auxiliary or component sciences of comparative philology, ethnology and archæology, have their share of these problems. Among them two of the most important are undoubtedly, in philology, the question of the origin of linguistic stocks, and in archæology, the question of the epoch at which man acquired the faculty of speech. In the language of modern diplomacy, these would be styled "burning questions," which must be settled before any hopeful progress can be made in other discussions. A brief consideration of these questions, in the light cast upon them by the most recent discoveries, may therefore be deemed to form an appropriate introduction to the work of our section. Briefly defined, then, our inquiry on this occasion will have for its subjects, or rather its subject,—for the two questions are closely connected, and form in reality but one problem,— the origin of languages and the antiquity of speaking man.

The question of the origin of languages must be distinguished from the different and larger question of the origin of language, which belongs rather to anthropology proper than to the science of linguistics, and will come under consideration in the later part of our inquiry. Nor yet does our question concern the rise and

development of the different tongues belonging to one linguistic stock or family, like the sixty languages of the Aryan or Indo-European stock, the twenty languages of the Hamito-Semitic family, the one hundred and sixty-eight languages enumerated by Mr. R. N. Cust as composing the great Bantu or South African family, and the thirty-five languages of the wide-spread Algonkin stock. Such idioms, however much they may differ, are in their nature only dialects. The manner in which these idioms originate is perfectly well understood. When two communities, in the barbarous or semi-barbarous stage, whose members spoke originally the same language, have been separated for a certain length of time, a difference of dialect, due to differences of climate, culture, customs and other circumstances, grows up between them. They can still understand each other's speech, but there are variances in pronunciation and in the use of certain words, by which they can readily be distinguished. In the progress of time these differences increase. Grammatical peculiarities are developed. Permutations of elementary sounds, like those which are manifested in the famous "Grimm's law," alter whole classes of words beyond the recognition of a hearer familiar only with the original speech. And, finally, two distinct languages are found to have come into being, so diverse in vocabulary and grammar that each must be learned as a foreign speech by the speakers of the other tongue. Yet, however wide may be the diversity, a careful analysis and comparison will always disclose the kinship, and indicate the common origin of the two languages.

But while the manner in which different languages of the same family arise is thus evident enough, not merely in theory, but in the numerous instances which have occurred within historic times, we have neither instance nor satisfactory theory to explain the distinction between the families themselves. When, for example, we have traced back the Aryan (or Indo-European) languages and the Semitic languages to their separate mother-tongues, which we are able to frame out of the scattered dialects, we find between these two mother-tongues a great gulf, which no explanation thus far proposed has sufficed to bridge over. How strongly the sense of this difficulty has been felt by the highest minds engaged in philological study will be evident from two striking examples. Sixty years ago, Baron William von Humboldt, who held in this branch of study the same position which was held by his illustrious brother in

the natural sciences, found it—as Dr. Brinton states in the excellent Introduction to his translation of Humboldt's "Philosophic Grammar of the American Languages"—"so contrary to the results of his prolonged and profound study of languages to believe, for instance, that a tongue like the Sanscrit could ever be developed from one like the Chinese, that he frankly said that he would rather accept at once the doctrine of those who attribute the different idioms of men to an immediate revelation from God." Fifty years later the distinguished representative of linguistic science in France, Professor Abel Hovelacque, pronounced in his admirable compendium, "La Linguistique" (1875), what may be deemed the "last word" of science on this subject. "Not only," he affirms, "is there no grammatical identity between the system of the Semitic languages and that of the Indo-European tongues, but these two comprehend inflection in a manner entirely different. Their roots are totally distinct; their formative elements are essentially different: and there is no relation between the two modes in which these elements perform their functions. The abyss between the two systems is not merely profound,—it is impassable."

Such then is the difficulty and the gravity of this question of the origin of languages,—a problem as serious and as fundamentally important for philological science as the question of the origin of species is deemed in biology; and, as has been already remarked, on the correct solution of this problem the progress and the future, not merely of philology, but of the whole "Science of Man," may be said to depend. For not until it is finally settled will the minds of the students of this science be in accord on the all-important question whether the human race belongs to many species or to only one.

Attempts to solve the problem have not been lacking. Several solutions have, indeed, been proposed, but no one of them has met with general acceptance. One of these suggested explanations takes into account the element of time. If man has existed for thousands of centuries, his speech might, it is supposed, have undergone in that vast period all the alterations required to produce these various linguistic stocks. But the conclusions of William von Humboldt and of Professor Hovelacque, already cited,—conclusions which express the generally received views of the best philologists,—show that this explanation cannot be entertained. If the development of a language like the Sanscrit from a language like the Chinese is inconceivable,—if the abyss between the Semitic

and the Indo-European tongues is impassable,—then it is clear that the mere element of time cannot help us in this difficulty. Moreover, we know, as a matter of fact, that the passage of time has not the effect supposed. It is certain that the distance between a Semitic tongue and an Aryan tongue in our day—as, for example, between the modern Arabic and the English—is no greater and no less than was the distance between the Semitic Assyrian and the Aryan Sanscrit a thousand years before the Christian era. If thirty centuries have made no appreciable change in the distinction between these two linguistic families, why should we suppose that three thousand centuries would produce any effect in that direction? But in reality, as will be seen in the progress of our inquiry, it is most probable that no such element of long-protracted time can be admitted in the present case.

Another theory which has been favored by some esteemed writers, and among others by Lyell in his famous work on the "Antiquity of Man," supposes that, when men first acquired the capacity of speech, their use of language was probably confined to a few monosyllabic roots, of vague and fluctuating import, and that, when those who spoke this primitive and half-formed tongue were scattered abroad, their imperfect speech developed into the widely different languages which became the mother-tongues of the various linguistic families. This ingenious hypothesis, however, is liable, as will be seen, to all the objections which the previously described theory has had to encounter, and, like that, does not stand the test either of reasoning or of facts. If those who used this primitive speech were—as we must suppose them to have been—human beings like those who now exist, their language was a language complete in all its parts: for no tribe of men has been found in any part of the world so low in the scale of humanity as not to have a complete and thoroughly organized language. This language may, like the Chinese and the Anamese, consist wholly or mainly of roots; but it is none the less complete, and—what is more important to the argument—none the less permanent. In the vast Chinese empire, after an existence of more than four thousand years, one spoken language prevails, with differences of dialect not so great as the differences which exist between the Romanic languages of Europe. If it be suggested that this permanence may be due to the existence of one government and of a written character, the same cannot be affirmed of the many monosyllabic languages be-

longing to the great linguistic families of Transgangetic India,—the Tibeto-Burman family, the Tai family, and the Mon-Anam family,—where sometimes, as is shown by Mr. Cust in his valuable work on the "Modern Languages of the East Indies," twenty different languages belonging to one linguistic stock are spoken by communities living under a dozen different governments, and in every stage of culture. Furthermore, it may be asked, How is it possible to suppose that the nineteen distinct linguistic stocks which have been found to exist in what is now the state of California can have originated in dialects of a monosyllabic language spoken thousands of years ago on another continent? Where did these dialects lose all traces of resemblance, and how did the speakers of them come to be living side by side in this narrow area? This theory, it will be seen, raises difficulties far greater than those which it undertakes to explain.

Finally, the latest proposed solution, and one which merits special attention for its scientific interest and the weight of authority in its favor, is the theory first propounded, I believe, by the distinguished Viennese ethnologist, Dr. Frederick Müller, and adopted by Dr. Ernest Haeckel, by Professor Hovelacque, by General Faidherbe, and other eminent authorities. This theory supposes that men, or rather the precursors of man, were at first incapable of speech, and that they acquired this capacity at different places. This opinion is so important that it should be stated in the language of one of its chief advocates. In his work, "La Linguistique," already quoted, Professor Hovelacque, after describing the impassable gulf which separates the Semitic and the Indo-European languages, adds that the case of these languages is the case of a considerable number of linguistic systems; and he proceeds: "The consequence of this fact is important. If, as we have shown, the faculty of articulate speech is the proper and the sole characteristic of man, and if the different linguistic systems, which we know, are irreducible, they must have come into existence separately, in regions entirely distinct. It follows that the precursor of man, the first to acquire the faculty of articulate language, has gained this faculty in different places at the same time, and has thus given birth to many human races originally distinct."

Dr. Frederick Müller, whose noble work, "The Outline of Linguistic Science" (*Grundriss der Sprachwissenschaft*), is for students of our time what the "Mithridates" of Adelung and Vater was to

those of a former generation,—the great thesaurus of philologic research and analysis,—not only maintains this view, but lays down specifically the division of race into which the speechless descendants of the primitive precursor of our kind—the *homo primigenius alalus*—had separated before they acquired the faculty of language. Yet, notwithstanding the weight which may be justly given to the opinions of such high authorities, it may be affirmed in this case, as in the case of the earlier theories, that the difficulties raised by the hypothesis are immeasurably greater than those which it is designed to remove.

The number of totally different linguistic stocks, so far as now known, is at the lowest computation over two hundred; and of these the greater portion belong to the western continent. The theory now under consideration supposes that both continents were in early times inhabited throughout by beings resembling men, but incapable of speech. It is evident that the process of this wide dispersion of beings in that semi-brutal condition must have occupied a vast space of time. We are required to believe that suddenly and separately, with no common impulse or cause, but at one time, all these scattered tribes, which had existed for countless ages without language, fortuitously acquired the faculty of speech, invented each its own language, and began to converse. Such a stupendous event—the simultaneous acquisition, by more than two hundred distinct communities of speechless beings, of the faculty which specially distinguishes man from the brute—would well deserve to be styled miraculous.

To come down to specific particulars,—many years ago, in making the first ethnographical survey of Oregon, I found that there were in that region no less than twelve linguistic stocks,—that is, families of languages as distinct from one another in words and grammar as the Semitic family is from the Indo-European. The able linguists of the Bureau of Ethnology, Messrs. Gatschet and Dorsey, have made further investigations in this region, and have visited portions of it which I was unable to reach. Their researches have confirmed my classification, and have added two or three additional stocks. South of this district, Mr. Stephen Powers, in his excellent Report on California, published by the same Bureau, has continued the survey in that direction, and has found sixteen additional linguistic stocks (besides three of the Oregon stocks) within the limits of that state. Thus, in a region not much larger

than France, we find at least thirty distinct families of languages existing together. We are expected to believe that thirty separate communities of speechless precursors of men, after living side by side in this inarticulate condition for an indefinite period, suddenly and simultaneously acquired the power of speech, and began at once to talk in thirty distinct languages. The mere statement of this grotesque proposition seems sufficient to refute it.

While some of the ablest reasoners have thus been groping vaguely and blindly, in wrong directions, for the solution of this problem, and while others, like Humboldt and Whitney, have given it up in despair, the simple and sufficient explanation has been lying close at hand, awaiting only, like many other discoveries in science, the observation of some facts of common occurrence to bring it to light. In the present case, the two observers who have made the conclusive facts known to us have both been Americans, and both of them writers of more than ordinary intelligence; but both were entirely unknown in this branch of investigation, and both, moreover, had the singular ill-fortune of publishing their observations in works of such limited circulation that their important contributions to science have hitherto failed to attain the notice they deserved. Their observations were made at about the same time, nearly twenty years ago, but published at different dates,—the first in 1868, the second ten years later. It was the latter publication which first attracted my attention, soon after its appearance, and led to a course of study and inquiry resulting in the facts and conclusions now to be detailed.

Before setting forth the facts, it will be well to state at once the result of the inquiry. Briefly, then, the plain conclusion to which all the observations point with irresistible force is, that the origin of linguistic stocks is to be found in what may be termed the language-making instinct of very young children. From numerous cases, of which the history has been traced, it appears that, when two children who are just beginning to speak are left much together, they sometimes invent a complete language, sufficient for all purposes of mutual intercourse, and yet totally unintelligible to their parents and others about them. It is evident that, in an ordinary household, the conditions under which such a language would be formed are most likely to occur in the case of twins. One of the most remarkable instances is that of which a record has been preserved in one of the publications to which reference has been

made. This is a volume, published in 1878, by Miss E. H. Watson, a lady of Boston, the authoress of several esteemed works on historical subjects. In performing the pious duty of giving to the world an essay by her father, the late George Watson, on "The Structure of Language, and the Uniform Notation and Classification of Vowels for all Languages," the editress has prefixed to it two essays of her own, on "The Origin of Language," and on "Spelling Reform," which show evidence of much reading and thought and contain many valuable suggestions. The volume bears the peculiar title, apparently adopted by Mr. Watson, of "The Universe of Language," and appeared under the auspices of the now defunct "Authors' Publishing Company," by whose lapse most of the edition was cast back upon the hands of the editress, and thus failed to obtain the attention and credit which its value should have insured.

The first of Miss Watson's essays in this volume comprises, in especial, one contribution to scientific knowledge,—her account of the "children's language,"—which she justly deemed to be of great value, and which is perhaps even more important than she supposed. It is presented by her as bearing upon the question of the origin of human speech. While it has undoubtedly a real interest in this respect, its main value resides in the light which it casts on the origin of linguistic stocks. There is nothing in the example which clearly proves that the children in question would have spoken at all if they had not heard their parents and others about them communicating by oral sounds,—though we may, on good grounds (as will be shown), believe that they would have done so. What the case really establishes is, that children who have thus learned to speak may invent a language of their own, different from all that they hear around them, and yet adequate to all the purposes of speech.

In the year 1860 two children, twin boys, were born in a respectable family residing in a suburb of Boston. They were in part of German descent, their mother's father having come from Germany to America at the age of seventeen; but the German language, we are told, was never spoken in the household. The children were so closely alike that their grandmother, who often came to see them, could only distinguish them by some colored string or ribbon tied around the arm. As often happens in such cases, an intense affection existed between them, and they were constantly together.

The remainder of their interesting story will be best told in the words of the writer, to whose enlightened zeal for science we are indebted for our knowledge of the facts. She thus relates it:—

"At the usual age these twins began to talk, but, strange to say, *not* their 'mother-tongue.' They had a language of their own, and no pains could induce them to speak anything else. It was in vain that a little sister, five years older than they, tried to make them speak their *native language*,—as it would have been. They persistently refused to utter a syllable of English. Not even the usual first words, 'papa,' 'mamma,' 'father,' 'mother,' it is said, did they ever speak; and, said the lady who gave this information to the writer,—who was an aunt of the children, and whose home was with them,—they were never known during this interval to call their mother by that name. They had their own name for her, but never the English. In fact, though they had the usual affections, were rejoiced to see their father at his returning home each night, playing with him, etc., they would seem to have been otherwise completely taken up, absorbed with each other. . . . The children had not yet been to school; for, not being able to speak their 'own English,' it seemed impossible to send them from home. They thus passed the days, playing and talking together in their own speech, with all the liveliness and volubility of common children. Their accent was *German*, — as it seemed to the family. They had regular words, a few of which the family learned sometimes to distinguish; as that, for example, for carriage, which, on hearing one pass in the street, they would exclaim out, and run to the window."

This word for carriage, we are told in another place was *nī-si-boo-a*, of which, it is added, the syllables were sometimes so repeated that they made a much longer word. This, unfortunately, is the only word of the language which Miss Watson was able to ascertain; but even from this one example some interesting inferences may be drawn. The speech was plainly not monosyllabic; and the word in question is neither English nor German. In the concluding syllables, if lengthened by repetition, we may perhaps discern an attempt to imitate the rumbling of a carriage. "The children," we are told, "went in the family by the name of the little 'Dutch boys'; and the father, at first inquiry of the writer, called their speech 'a mixture of German and English.' But the children at that time had never heard any German spoken; there-

fore it could not have been the former; and if some English words were picked up—as would be but probable—they seem to have been so transformed that they were not recognizable as such, unless rarely. . . .The mother relates that, although she could not understand their language, she contrived, by attention, to discover what they wished or meant."

If the quick ear of a mother, after years of intercourse, could not discern the English words, it is clear that they were not used in a form which would have properly entitled them to that name. The important information is added, that, "even in that early stage, the language was complete and full; that is, it was all that was needed. The children were at no loss to express themselves in their plays, their 'chatterings' with each other, as our informant expressed it, all day. Indeed, the writer would gather from the description given that they were more than usually animated between themselves."

The sequel of the story, as graphically told by the authoress, has an interest, as showing that the language spoken around these children was to them really a foreign speech. "It finally seeming hopeless that they were going to learn their 'own tongue,' as we call it, it was concluded to send them to a school in the neighborhood, they being now six or seven years old. For a week, as the lady teacher described to whom they were sent, they were perfectly mute; not a sound could be heard from them, but they sat with their eyes intently fixed upon the children, seeming to be watching their every motion,— and no doubt, listening to every sound. At the end of that time they were induced to utter some words, and gradually and naturally they began, for the first time, to learn their 'native English.' With this accomplishment, the other began, also naturally, to fade away, until the memory, with the use of it, passed from their mind."

We cannot but share in the regret expressed by the accomplished authoress that she was not acquainted with these facts until it was too late to preserve a record of the language itself, which, it is evident, would have been of great scientific interest. Indeed, but for the facts now to be related, a suspicion might naturally remain, in spite of all that is said of the total strangeness of the children's speech, that it was, after all, only an exaggerated specimen of ordinary "baby-talk,"— a mere babble of imperfect English, mixed with some mimicries of natural sounds. Most fortunately,

another example affords the precise evidence required to dispel all such suspicion. Though in the case now to be described the circumstances were somewhat different, and the language was probably less complete than in the instance just recorded, yet it happened by good fortune, that a careful and scientific observer was in a position to preserve at least a portion of it for our information. While these interesting twins were chattering their peculiar language in Boston, a little four-year-old girl and her younger brother in Albany were perplexing their parents by a similar vagary. A clear and satisfactory account of this phenomenon was given by the late E. R. Hun, M.D., of that city, in an article published in the "Monthly Journal of Psychological Medicine (in the volume for 1868), under the title of "Singular development of Language in a Child." For my knowledge of this most important evidence, as well as for many other valuable suggestions, I have to thank our distinguished associate, Dr. Brinton, whose attention no essential fact relating to his favorite sciences is likely to escape.

The statements with which Dr. Hun commences his account are too succinct to be abridged. "The subject of this observation," he writes, "is a girl aged four and one-half years, sprightly, intelligent, and in good health. The mother observed, when she was two years old, that she was backward in speaking, and only used the words 'papa' and 'mamma.' After that she began to use words of her own invention, and though she understood readily what was said, never employed the words used by others. Gradually she enlarged her vocabulary until it had reached the extent described below. She has a brother eighteen months younger than herself, who has learned her language, so that they talk freely together. He, however, seems to have adopted it only because he has more intercourse with her than with others; and in some instances he will use a proper word with his mother, and his sister's word with her. She, however, persists in using only her own words, though her parents, who are uneasy about her peculiarity of speech, make great efforts to induce her to use proper words. As to the possibility of her having learned these words from others, it is proper to state that her parents are persons of cultivation, who use only the English language. The mother has learned French, but never uses the language in conversation. The domestics, as well as the nurses, speak English without any peculiarities, and the child has heard even less than usual of what is called

baby-talk. Some of the words and phrases have a resemblance to the French; but it is certain that no person using that language has frequented the house, and it is doubtful whether the child has on any occasion heard it spoken. There seems to be no difficulty about the vocal organs. She uses her language readily and freely, and when she is with her brother they converse with great rapidity and fluency."

Dr. Hun then gives the vocabulary, which, he states, was such as he had "been able at different times to compile from the child herself, and especially from the report of her mother." From this statement we may infer that the list probably did not include the whole number of words in this child-language. It comprises, in fact, only twenty-one distinct words, though many of these were used in a great variety of acceptations, indicated by the order in which they were arranged, or by compounding them in various ways. As we know, however, on excellent authority, that the conversation of English laborers has been found to be carried on with no more than a hundred words, we may believe that the talk of the children might be fluent enough with a much more limited vocabulary. "I once listened,"—writes Archdeacon Farrar, in his work on "Language and Languages,"—"for a long time together to the conversation of three peasants who were gathering apples among the boughs of an orchard, and, as far as I could conjecture, the whole number of words they used did not exceed a hundred; the same word was made to serve a variety of purposes." This, it will be seen, was exactly the case with the language of these children.

Three or four of the words, as Dr. Hun remarks, bear an evident resemblance to the French, and others might, by a slight change, be traced to that language. He was unable, it will be seen, to say positively that the girl had never heard the language spoken; and it seems not unlikely that, if not among the domestics, at least among the persons who visited them, there may have been one who amused herself, innocently enough, by teaching the child a few words of that tongue. It is, indeed, by no means improbable that the peculiar linguistic instinct may thus have been first aroused in the mind of the girl, when just beginning to speak. Among the words showing this resemblance are *feu* (pronounced, we are expressly told, like the French word), used to signify "fire, light, cigar, sun;" *too* (the French *tout*), meaning "all, everything;" and *ne pa* (whether pronounced as in French, or other-

wise, we are not told), signifying "not." *Petee-petee*, the name given to the boy by his sister, is apparently the French *petit*, little; and *ma*, I, may be from the French *moi*, me. If, however, the child was really able to catch and remember so readily these foreign sounds at such an early age, and to interweave them into a speech of her own, it would merely show how readily and strongly in her case the language-making faculty was developed.

Of words formed by imitation of sounds, the language shows barely a trace. The mewing of the cat evidently suggested the word *mea*, which signified both cat and furs. For the other vocables which make up this speech, no origin can be conjectured. We can merely notice that in some of the words the liking which children and some races of men have for the repetition of sounds is apparent. Thus we have *migno-migno*, signifying "water, wash, bath;" *go-go*, "delicacies, as sugar, candy, or dessert;" and *waia-waiar*, "black, darkness, or a negro." There is, as will be seen from these examples, no special tendency to the monosyllabic form. *Gummigar*, we are told, signifies "all the substantials of the table, such as bread, meat, vegetables, etc.;" and the same word is used to designate the cook. The boy, it is added, does not use this word, but uses *gna-migna*, which the girl considers a mistake. From which we may gather that even at that tender age the form of their language had become with them an object of thought; and we may infer, moreover, that the language was not invented solely by the girl, but that both the children contributed to frame it.

Of miscellaneous words may be mentioned *gar*, "horse;" *deer*, "money of any kind;" *beer*, "literature, books, or school;" *peer*, "ball;" *bau*, "soldier, music;" *odo*, "to send for, to go out, to take away;" *keh*, "to soil;" *pa-ma*, "to go to sleep, pillow, bed." The variety of acceptations which each word was capable of receiving is exemplified in many ways. Thus *feu* might become an adjective, as *ne-pa feu*, "not warm." The verb *odo* had many meanings, according to its position or the words which accompanied it. *Ma odo*, "I (want to) go out;" *gar odo*, "send for the horse;" *too odo*, "all gone." *Gaän* signified God; and we are told, "When it rains, the children often run to the window, and call out, *Gaän odo migno-migno, feu odo*, which means, 'God take away the rain, and send the sun;' *odo* before the object meaning to 'take away,' after the object, 'to send.'" From this remark

and example we learn, not merely that the language had—as all real languages must have—its rules of construction, but that these were sometimes different from the English rules. This also appears in the form *mea waia-waiar*, "dark furs" (literally, "furs dark"), where the adjective follows its substantive.

The odd and unexpected associations which in all languages govern the meaning of words are apparent in this brief vocabulary. We can gather from it that the parents were Catholics, and punctual in church observances. The words *papa* and *mamma* were used separately in their ordinary sense; but when linked together in the compound term *papa-mamma*, they signified (according to the connection, we may presume) "church, prayer-book, cross, priest, to say their prayers." *Bau* was "soldier;" but, we are told, from seeing the bishop in his mitre and vestments, thinking he was a soldier, they applied the word *bau* to him. *Gar odo* properly signified "send for the horse;" but as the children frequently saw their father, when a carriage was wanted, write an order and send it to the stable, they came to use the same expression (*gar odo*) for pencil and paper.

There is no appearance of inflection, properly speaking, in the language; and this is only what might be expected. Very young children rarely use inflected forms in any language. The English child of three or four years says, "Mary cup," for "Mary's cup;" and "Dog bite Harry" will represent every tense and mood. It is by no means improbable that if the children had continued to use their own language for a few years longer, inflections would have been developed in it, as we see that peculiar forms of construction and novel compounds—which are the germs of inflection—had already made their appearance.

These two recorded instances of child-languages have led to further inquiries, which, though pursued only for a brief period, and in a limited field, have shown that cases of this sort are by no means uncommon. An esteemed physician of my acquaintance, whose childhood was passed in the city of Kingston, Ontario, has informed me of a case within his own knowledge which bears a remarkable resemblance to that of the Albany children. It occurred in that city nearly thirty years ago, when my informant was about seven years old; but his recollection of it is perfectly distinct. A widower with several children, one of whom was a boy between four and five years old, married a widow with a single child,—a girl, some-

what younger than the boy. They lived directly opposite the residence of my friend's parents, and he knew the children intimately. The boy was unusually backward in his speech, and at the time of the marriage spoke imperfectly. He and the little girl soon became inseparable playmates, and formed a language of their own, which was unintelligible to their parents and friends. They had names of their own invention for all the objects about them, and must have had a corresponding supply of verbs and other parts of speech, as their talk was fluent and incessant. My informant, with his brother and the other children who lived near them, often listened to this chatter with great amusement, and came at last to recognize a number of the most common expressions. The only one which he can now remember was the word for cat, which fastened itself in his mind by its oddity. The little philologists had a favorite cat, which they often held aloft for the admiration of the spectators across the street, shouting to them its extraordinary name of *shindikik*. This term, like the solitary word preserved of the speech of the Boston children, proves at least that the language had passed beyond the infantile or Chinese stage, when every word is a monosyllable, usually ending in a vowel. The mother of the little girl became at length so much disquieted by the persistency of the children in refusing to speak English, that she finally resorted to the expedient of separating them, and placed the daughter for a time under the care of a relative residing at a distance. The children soon forgot their abnormal speech, and, as both the parents are dead, it is not likely that any more relics of it will be recovered.

How soon such memories fade from the minds of both speakers and hearers, and how little attention such incidents attract, is shown by another case, which occurred some twenty years ago in the family of one of my nearest neighbors and friends, but was so little noticed that I had never heard of it until the present year. In this family the two youngest children — a boy and a girl — were twins, and as usually happens, were left much together. When they were three or four years old they were accustomed, as their elder sister informs me, to talk together in a language which no one else understood. The other members of the family called it their "gibberish," but otherwise paid little attention to it. The father would sometimes say, "Hear those children chattering!" and the other members of the family would listen, and smile at the

stream of unintelligible sounds. The twins were wont to climb into their father's carriage in the stable, and "chatter away," as my informant says, for hours in this strange language. Their sister remembers that it sounded as though the words were quite short. But the single word which survives in the family recollection is a dissyllable,—the word for milk, which was *cully*. The little girl accompanied her speech with gestures, but the boy did not. As they grew older, they gradually gave up their peculiar speech. The boy is dead. The girl, now an intelligent and accomplished young lady, has totally forgotten the words of their childish speech, though she remembers well the fact of using it and the amusement it excited. She remembers also that the others spoke of them as "talking Scotch," or "in Scotch fashion." Their father, a well-educated professional gentleman, was of Scottish birth, but had lived much in England; and neither he nor any of the children had any marked accent differing from that of ordinary English speech.

A case which recalls that of the Boston boys is related to me by a lady friend who was educated in Toronto. She remembers perfectly well the amusement caused, in the school which she attended in her early childhood, by two little boys, sons of a wealthy gentleman of that city, who were accustomed to converse together in a language of their own. Their ages were about five or six, one being somewhat more than a year older than the other. The youngest, however, was slightly the taller of the two. They were fine, intelligent boys, and were always together, both at home and in the school. My informant knew the family, which was a rather large one,—five boys and a girl. These children were left much to themselves, and had a language of their own, in which they always conversed. The other children in the school used to listen to them as they chattered together, and laugh heartily at the strange speech of which they could not understand a word. The boys spoke English with difficulty, and very imperfectly, like persons struggling to express their ideas in a foreign tongue. In speaking it, they had to eke out their words with many gestures and signs to make themselves understood; but in talking together in their own language, they used no gestures, and spoke very fluently. She remembers that the words which they used seemed quite short. In imitating from memory their mode of speech she uses monosyllables. They had a nurse, an intelligent middle-aged woman, who brought them to the school in the morning, and came

for them in the afternoon. She had had the care of them from infancy, and understood their language, but did not speak it. She was accustomed to speak to them in English, and they would reply to her in their own tongue. They learned but little at the school, and had apparently been sent there chiefly to accustom them to be with children of their own age, and to learn to speak like them. My friend knew them in after life, as grown-up young men, when they spoke English like other people.

But it is needless to multiply examples. The instances thus recorded do not by any means exhaust the list. I have not yet had the fortunate opportunity—which Dr. Hun enjoyed and used to such good advantage—of personally hearing and investigating such a child language. But as it is evident that its development is not a fact of very rare occurrence, we may hope, now that attention has been drawn to the matter, that this interesting subject of inquiry will soon be thoroughly studied by competent observers. These cases, it must be remembered, are, after all, merely intensified forms of a phenomenon which is of constant recurrence. The inclination of very young children to employ words and forms of speech of their own is well known, though it is only under peculiar circumstances that this language acquires the extent and the permanence which it attained in the cases now recorded. Along with this inclination of children, a corresponding disposition of their elders in conversing with them will be noticed. The "baby-talk" in which mothers and nurses in all communities, civilized and savage, are wont to indulge, is in some respects totally distinct from their ordinary speech. It is utterly devoid of inflections, of articles, and of pronouns, has its own pronunciation, its own syntax and construction, and many peculiar words. The importance of this baby-talk as an element of linguistic science has been recognized by eminent scientific investigators. Dr. Tylor, in the fifth chapter of his work on "Primitive Culture," touches upon this subject with some noteworthy remarks and suggestions, of which the general tenor is strikingly confirmed by the speech of the Albany children. "Children's language," he observes, "may give a valuable lesson to the philologist." After quoting many examples of infantile words in use in various countries, he adds: "In this language, the theory of root-sounds fairly breaks down." "It is obvious," he continues, "that the leading principle of their formation is, not to adopt words distinguished by the expressive charac-

ter of their sound, but to choose somehow a fixed word to answer a given purpose." So Mr. George P. Marsh, in his "Lectures on the English Language," remarks, that the question whether the power of speech is a faculty or an art may be answered "in a general way, by saying that the use of articulate language is a faculty inherent in man, though we cannot often detect any natural and necessary connection between a particular object and the vocal sound by which this or that people presents it." And he adds: "There can be little doubt that a colony of children, reared without hearing sounds uttered by those around them, would at length form for themselves a speech." Many other citations might be made, showing that philologists have more than once been fairly on the track of the cause to which the origin of linguistic families is due. If they have failed to follow to its conclusion the path into which their intuitions had led them, it has simply been from lack of the evidence now at hand.

In the light of the facts which have now been set forth, it becomes evident that, to insure the creation of a speech which shall be the parent of a new linguistic stock, all that is needed is that two or more young children should be placed by themselves in a condition where they will be entirely, or in a large degree, free from the presence and influence of their elders. They must, of course, continue in this condition long enough to grow up, to form a household, and to have descendants to whom they can communicate their new speech. We have only to inquire under what circumstances an occurrence of this nature can be expected to take place.

There was once a time when no beings endowed with articulate speech existed on this planet. When such beings appeared, whether at one centre or at several, the spread of this human population over the earth would necessarily be gradual. So very slow and gradual, indeed, has it been, that many outlying tracts—Iceland, Madeira, the Azores, the Mauritius, St. Helena, the Falkland Islands, Bounty Island, and others—have only been peopled within recent historical times, and some of them during the present century. This diffusion of population would take place in various ways, and under many different impulses;—sometimes as the natural result of increase and overcrowding, sometimes through the dispersion caused by wars, frequently from a spirit of adventure, and occasionally by accident, as when a canoe was drifted on an unknown shore. In most instances, a considerable party, compris-

ing many families, would emigrate together. Such a party would carry their language with them; and the change of speech which their isolation would produce would be merely a dialectical difference, such as distinguishes the Greek from the Sanscrit, or the Ethiopic from the Arabic. The basis of the language would remain the same. No length of time, so far as can be inferred from the present state of our knowledge, would suffice to disguise the resemblance indicating the common origin of such dialect-languages. But there is another mode in which the spread of population might take place, that would lead in this respect to a very different result. If a single pair, man and wife, should wander off into an uninhabited region, and there, after a few years, both perish, leaving a family of young children to grow up by themselves and frame their own speech, the facts which have been adduced will show that this speech might, and probably would, be an entirely novel language. Its inflectiuns would certainly be diflerent from those of the parent tongue, because the speech of children under five years of age has commonly no inflections. The great mass of vocables, also, would probably be new. The strong language-making instinct of the younger children would be sufficient to overpower any feeble memory which their older companions might retain of the parental idiom. The natural disposition of the oldest child, indeed, would be to yield to the youngest in this regard. He would feel it to be essential that he should make his little brother or sister understand him, and he would adopt without hesitation any manner of speech that would insure this object. The baby-talk, the "children's language," would become the mother-tongue of the new community, and of the nation that would spring from it.

Those who are familiar with the habits of the hunting tribes of America know how common it is for single families to wander off from the main band in this manner, — sometimes following the game, sometimes exiled for offences against the tribal law, sometimes impelled by the all-powerful passion of love, when the man and woman belong to families or classes at deadly feud or forbidden to intermarry. In these latter cases, the object of the fugitives would be to place as wide a space as possible between themselves and their irate kindred. In modern times, when the whole country is occupied, their flight would merely carry them into the territory of another tribe, among whom, if well received, they would quickly be absorbed. But in the primitive period, when a vast uninhabited

region stretched before them, it would be easy for them to find some sheltered nook or fruitful valley, in which they might hope to remain secure, and rear their young brood unmolested by human neighbors.

If, under such circumstances, disease or the casualties of a hunter's life should carry off the parents, the survival of the children would, it is evident, depend mainly upon the nature of the climate and the ease with which food could be procured at all seasons of the year. In ancient Europe, after the present climatal conditions were established, it is doubtful if a family of children under ten years of age could have lived through a single winter. We are not, therefore, surprised to find that no more than four or five linguistic stocks are represented in Europe, and that all of them, except the Basque, are believed, on good evidence, to have been of comparatively late introduction. Even the Basque is traced by some, with much probability, to a source in North Africa. Of northern America, east of the Rocky Mountains and north of the tropics, the same may be said. The climate and the scarcity of food in winter forbid us to suppose that a brood of orphan children could have survived, except possibly, by a fortunate chance, in some favored spot on the shore of the Mexican Gulf, where shell-fish, berries and edible roots are abundant and easy of access.

But there is one region where Nature seems to offer herself as the willing nurse and bountiful step-mother of the feeble and unprotected. Of all countries on the globe, there is probably not one in which a little flock of very young children would find the means of sustaining existence more readily than in California. Its wonderful climate, mild and equable beyond example, is well known. Mr. Cronise, in his volume on the "Natural Wealth of California," tells us, that "the monthly mean of the thermometer at San Francisco in December, the coldest month, is 50°; in September, the warmest month, 61°." And he adds: "Although the state reaches to the latitude of Plymouth Bay on the north, the climate, for its whole length, is as mild as that of the regions near the tropics. Half the months are rainless. Snow and ice are almost strangers, except in the high altitudes. There are fully two hundred cloudless days in every year. Roses bloom in the open air through all seasons." Not less remarkable than this exquisite climate is the astonishing variety of food, of kinds which seem to offer themselves to the tender hands of children. Berries of many sorts—straw-

berries, blackberries, currants, raspberries, and salmon-berries—are indigenous and abundant. Large fruits and edible nuts on low and pendent boughs may be said, in Milton's phrase, to "hang amiable." Mr. Cronise enumerates, among others, the wild cherry and plum, which "grow on bushes;" the barberry, or false grape (*Berberis herbosa*), a "low shrub," which bears edible fruit; and the Californian horse-chestnut (*Æsculus Californica*), "a low, spreading tree or shrub, seldom exceeding fifteen feet high," which "bears abundant fruit, much used by the Indians." Then there are nutritious roots of various kinds maturing at different seasons. Fish swarm in the rivers, and are taken by the simplest means. In the spring, Mr. Powers informs us, the whitefish "crowd the creeks in such vast numbers that the Indians, by simply throwing in a little brushwood to impede their motion, can literally scoop them out." Shell-fish and grubs abound, and are greedily eaten by the natives. Earth worms, which are found everywhere and at all seasons, are a favorite article of diet. As to clothing, we are told by the authority just cited that "on the plains all adult males and all children up to ten or twelve went perfectly naked,—while the women wore only a narrow strip of deer-skin around the waist." Need we wonder that, in such a mild and fruitful region, a great number of separate tribes were found, speaking languages which a careful investigation has classed in nineteen distinct linguistic stocks?

The climate of the Oregon coast region, though colder than that of California, is still far milder and more equable than that of the same latitude in the east; and the abundance of edible fruits, roots, river-fish, and other food of easy attainment, is very great. A family of young children, if one of them were old enough to take care of the rest, could easily be reared to maturity in a sheltered nook of this genial and fruitful land. We are not, therefore, surprised to find that the number of linguistic stocks in this narrow district, though less than in California, is more than twice as large as in the whole of Europe, and that the greater portion of these stocks are clustered near the Californian boundary.

It is not, however, necessary to suppose that in every instance both parents had perished. If only one of them died, leaving four or five children,—the oldest perhaps not more than six years old,—the surviving parent, having no adult companion to converse with, would infallibly, as a matter of absolute necessity, adopt the

language of the children, and to a large extent fall in with their ways of thought. The only difference would be, that when, with the growth of the children in years and intelligence, grammatical inflections came to be gradually developed, these inflections, if not the same as those of the parent's mother-tongue, would probably be of a similar cast. Indeed, this to some extent might be expected, even when both parents had perished. Some reminiscences of the parental speech would probably remain with the older children, and be revived and strengthened as their faculties gained force. Thus we may account for the fact which has perplexed all inquirers, that certain unexpected and sporadic resemblances, both in grammar and in vocabulary, which can hardly be deemed purely accidental, sometimes crop up between the most dissimilar languages. Such are the surprising resemblances between some of the Aryan and Semitic numerals; and such are the curious concordances between some of the Aryan and the Malayo-Polynesian roots, which perplexed and for a time misled so great a philologist as Bopp. Among languages of the polysynthetic class, few are more unlike than the Algonkin, the Iroquois, and the Dakota; yet in all three the word for foot is almost identical. This word is *sit*, or, without the terminal consonant, *si* (in English orthography *see*). A word so brief, distinct, and easy of utterance would be likely to survive in the memory of any child of four or five years who had heard it as frequently repeated by the mother as this word would certainly be.

We must also remember that a certain similarity in the form or mould of all idioms spoken by tribes of the same race, even when these idioms originated from such child-languages, would be apt to arise, partly from similarity of character and circumstances, and partly from the inherited conformation of the brain. Of the former class of influences, — the effect of the environing circumstances, first on the character and then on the speech,— we have an elaborate and most suggestive discussion in Mr. Byrne's recent work on the "Principles of the Structure of Language." As regards the inherited powers of mind, we have to consider that when, in any group of children, the faculty of language was strong, their speech would probably develop into a highly complex idiom, like the Aryan, the Semitic, the Basque, or the Algonkin; when this faculty was less powerful, the speech would be simpler, like the Malayan, the Mongol, and the Maya; and when it was very weak,

the language would remain, like the Chinese and Anamese, in the monosyllabic or infantile stage. It is proper, further, to bear in mind, that a strong or weak capacity for language does not necessarily imply a corresponding strength or weakness of the other intellectual powers. On this point Professor Whitney, in his "Life and Growth of Language," well observes: "The Chinese is a most striking example of how a community of a very high grade of general ability may exhibit an extreme inaptitude for fertile linguistic development. We may suitably compare this with the grades of aptitude shown by various races for plastic, or pictorial, or musical art, which by no means measure their capacity for other intellectual or spiritual products."

A glance at other linguistic provinces will show how aptly this explanation of the origin of language-stocks everywhere applies. Tropical Brazil is a region which combines perpetual summer with a profusion of edible fruits and other varieties of food, not less abundant than in California. Here, if anywhere, there should be a great number of totally distinct languages. We learn on the best authority, that of Baron J. J. von Tschudi, in the Introduction to his recent work on the "Organism of the Khetshua Language," that this is the fact. He says: "I possess a collection made by the well-known naturalist, Joh. Natterer, during his residence of many years in Brazil, of more than a hundred languages, lexically completely distinct, from the interior of Brazil." And he adds: "The number of so-called *isolated* languages—that is, of such as, according to our present information, show no relationship to any other, and which therefore form distinct stocks of greater or less extent—is in South America very large, and must, on an approximate estimate, amount to many hundreds. It will perhaps be possible hereafter to include many of them in larger families, but there must still remain a considerable number for which this will not be possible."

The explanation which the learned writer gives of this great diversity of languages is that which has been heretofore received by most philologists. "The cause of this remarkable phenomenon," he writes, "is evidently to be found in the subdivision of the Indian population. The evidence of language leads to the conclusion that the separation of families and tribes from the main body of the descendants of the first incomers must have taken place in very early times. In their wanderings toward the south, the de-

scendants of these straggling hordes must have separated again and again. Many of them may have been brought into positions which were remote from the great lines of migration, may there have remained more or less isolated, may have naturally, in their new relations and surroundings, formed a new vocabulary, and have cast aside and forgotten much of their old speech as useless in their new circumstances. But this forgetting and new-making took place not only in the names given to objects, but in all linguistic expressions as well, including the structure of words and sentences. Languages wholly new arose. Frequently a single family, which broke off from the horde, and moved away in a separate course, has given rise to an entirely new speech."

If by the phrase "a single family" we could understand such a group of young children as has just been described, this explanation would exactly accord with the view proposed in this paper. This, however, is evidently not the writer's meaning; and, with all due deference to the eminent and justly esteemed author, I may venture to affirm that the process which he describes is opposed to all experience and observation. There is no instance known of a tribe or family of grown-up persons losing their original language in the way he has supposed. The branches of the great Malayo-Polynesian family, scattered over a thousand islands, large and small, from Madagascar to Hawaii, have retained everywhere the mass of their vocabulary and grammar with remarkable uniformity. The thorough analyses furnished by Dr. F. Müller, in his latest work, leave no room for doubt on this point. It is plain that each island has been peopled by one or more canoe-loads of emigrants, bringing their language with them. A still more striking example is to be noted in Australia, where a vast region, larger than Brazil, is found inhabited by hundreds, perhaps thousands, of petty tribes, as completely isolated as those of South America, but all speaking languages of one stock. And if we inquire why many different linguistic stocks have not arisen in that region, as in California, Brazil, and Central Africa, the explanation presents itself at once. Though the climate is as mild as in any of these regions, the other conditions are such as would make it impossible for an isolated group of young children to survive. The whole of Australia is subject to severe droughts, and is so scantily provided with edible products that the aborigines are often reduced to the greatest straits. It is well known that an entire exploring party

of white men, well provided with fire-arms, perished of famine in attempting to traverse the interior. The suspicious and unsocial character of the Australian natives, the smallness of their tribes, their wide dispersion, and the little communication between them, are all well-known facts. If linguistic stocks could arise in the way supposed by Herr von Tschudi, there should be hundreds in Australia; but there is only one.

A curious ethnological fact, which tends strongly to confirm the view of the origin of linguistic stocks now proposed, is the circumstance that, as a general thing, each linguistic family has its own mythology. This remarkable fact has been noticed, and well set forth, by Major Powell; and it had, I may add, already occurred to myself in connection with the present inquiry, in which it finds its sufficient explanation. Of course, when the childish pair or group, in their isolated abode, framed their new language and transmitted it to their descendants, they must necessarily at the same time have framed a new religion for themselves and their posterity; for the religious instinct, like the language-making faculty, is a part of the mental outfit of the human race.

But we are now brought face to face with another problem of great difficulty. The view which has just been presented shows that all the vast variety of languages on earth may have arisen within a comparatively brief period; and many facts seem to show that the peopling of the globe by the present nations and tribes of men is a quite recent event. The traditions of the natives of America, North and South, have been gathered and studied of late years, by scientific inquirers, with great care and valuable results. All these traditions, Eskimo, Algonkin, Iroquois, Choctaw, Mexican, Maya, Chibcha, Peruvian, represent the people who preserved them as new-comers in the regions in which they were found by the whites. Ethnologists are aware that there is not a tradition, a monument, or a relic of any kind, on this continent, which requires us to carry back the history of any of its aboriginal tribes, of the existing race, for a period of three thousand years. In the Pacific Islands the recent investigations have had a still more striking and definite result. We know, on sufficiently clear evidence, the times when most of the groups, from New Zealand to the Sandwich Islands, were first settled by their Polynesian occupants. None of the dates go back beyond the Christian era. Some of them come down to the last century. In Australia the able missionary investigators

have ascertained that the natives had a distinct tradition of the arrival of their ancestors, who entered by the northwest coast. It is most unlikely that, among such a barbarous and wandering race, a tradition of this nature should be more than two thousand years old. Probably it is much less ancient. We know positively that the neighboring group of New Zealand was settled only about five hundred years ago. Passing on to the old continent, we find that the Japanese historical traditions go back, and that doubtfully, only to a period about twenty-five hundred years ago; those of China, only about four thousand years; those of the Aryans, vaguely, to about the same time; the Assyrians, more surely, a little longer; and the Egyptians to the date fixed by Lepsius for Menes, not quite four thousand years before Christ. No evidence of tradition, or of any monument of social man, points to his existence on the earth at a period exceeding seven thousand years before the present time. Yet the investigations which have followed the discoveries of Boucher de Perthes have satisfied the great majority of scientific men that human beings have been living on the globe for a term which must be computed, not by thousands of years, but by tens and probably hundreds of thousands. Writers of all creeds, and of all opinions on other subjects, concur in the view that the existence of man goes back to a remote period, in comparison with which the monuments of Egypt are but of yesterday; and yet these monuments, as has been said, are the oldest constructions of social man which are known to exist. How shall we explain this surprising discrepancy? How shall we account for the fact that man has existed for possibly two hundred thousand years, and has only begun to form societies and to build cities within less than seven thousand years? In other words, how, as scientific men, shall we bring the conclusions of geology and palæontology into harmony with those of archæology and history?

Fortunately, the geologists and physiologists themselves, by their latest discoveries, have furnished the means of clearing up the perplexities which their earlier researches had occasioned. We learn from these discoveries that, while a being entitled to the name of man has occupied some portions of the earth during a vast space of time, in one and perhaps two geological eras, the acquisition by this being of the power of speech is in all probability an event of recent occurrence. The main facts on which this opinion is based must necessarily, in this summary, be very briefly stated. For

other evidences, reference must be made to the sources where they will be found fully set forth.

The question of the existence of man in the tertiary era has been so thoroughly and ably discussed by my predecessor in this office, Professor Morse, in his address at the Philadelphia meeting in 1884, that I need not add a word on that subject. The fact that man existed in the subsequent period, which is known among English geologists as the pleistocene era and in France more commonly as the quaternary age, is questioned by no one. The men of that era, the Palæolithic men, as they are styled, are distinguished by the investigators, as is well known, into two distinct races, belonging to widely different epochs. These races are variously designated by the eminent authorities to whom I shall have occasion to refer, and who, while they differ on some points, are on the main question of the existence and the distinction of these races fully in accord. These authorities, it may here be stated, are, for France, Prof. de Quatrefages and Prof. G. de Mortillet, and for England, Prof. Boyd Dawkins. The views of M. de Quatrefages are set forth in his work entitled "Hommes Fossiles et Hommes Sauvages," published in 1884, and in his well-known treatise on "The Human Species," of which the eighth edition has appeared during the present year. The work of M. de Mortillet, "Le Préhistorique," appeared in 1883, and that of Prof. Boyd Dawkins, "Early Man in Britain," was published in 1880. Those who had the pleasure of hearing Professor Dawkins at the Montreal meeting of the British Association, in 1884, are aware that his researches subsequent to the publication of that work had only confirmed the views expressed in it. I have also to refer to the work of Dr. Paul Topinard, "L'Anthropologie," of which the fourth edition appeared in 1884; to the work of Prof. George H. von Meyer, of Zurich, on the "Organs of Speech" (1884), to the monograph of Dr. Robert Baume, of Berlin, on the "Jaw-Fragments of La Naulette and the Schipka Cave" (1884), and the work of Prof. Robert Hartmann, of Berlin, on "Anthropoid Apes," which has just appeared.

Professor Dawkins styles the earlier Palæolithic race the "River-drift men," and the later "the Cave-men." The River-drift men were, in his view, hunters and savages of the lowest grade. In his opinion, the race is now "as completely extinct as the wooly rhinoceros or the cave bear." We have, he considers, no clew to its ethnology; and its relation to the race that succeeded it is doubt-

ful. The Cave-men were of a much higher order, and were especially remarkable for their artistic talents. He is inclined to believe that their descendants survive in the Eskimo; and whether we accept this view or not, we learn from it that, in the opinion of this eminent investigator, the Cave-men were men of the present race. M. de Quatrefages designates the two races from noted localities where their osseous remains were found. The River-drift man is with him the "man of Canstadt," from the place near which the portion of a cranium belonging to this race was discovered; and the Cave-man is the "man of Cro-Magnon," a well-known locality where several skeletons of this race were brought to light. M. de Mortillet draws his designations from the places in which the implements used by the different races are found in their most typical form. The man of the earlier race is with him the "Chellean man," from Chelles, a place in the Department of Seine-et-Marne: while the later is the Magdalenian man, from La Madéleine in the Department of La Dordogne. He makes two intermediate races, the Mousterian and the Solutrean, which Professor Dawkins is inclined to combine with the Magdalenian in a single race, corresponding to his Cave-men. But in one respect M. de Mortillet makes an even stronger distinction than that of Professor Dawkins between the earlier and later races. Professor Dawkins expresses no opinion on the question whether the River-drift men were or were not endowed with the faculty of speech. Prof. de Mortillet is clear that they were not. This view might fairly enough, as will be seen, be based on the pithecoid character of their remains, and the low grade of intellect shown by their implements; but M. de Mortillet finds a remarkable, and in his opinion, a decisive evidence, in a lower jaw belonging to this race, which was discovered in 1866 in the cave of La Naulette in Belgium. It is only a fragment, but it contains the central curve, or symphysis, forming the chin. In the inner centre of the ordinary human jaw, there is at this curve a small bony projection or excrescence, usually somewhat rough to the touch, which is known to English and American anatomists as the "mental tubercle," or "the genial tubercle." By French writers it is termed the *apophyse géni*, or genial apophysis, and by German authors the *spina mentalis*. These epithets, "mental" and "genial," it may be remarked, are not the common English adjectives with which we are familiar. "Mental" is here derived, not from the Latin *mens*, the mind, but from *mentum*, the chin, and, in the

same way, "genial" in this case is to be referred, not to the Greek γένος, family or kindred, but to γένυς (or its derivative γενειάς), which means in that language the chin or under-jawbone. With this preface, I give in full the author's description of this remarkable relic. The bone is small, and is supposed to have been that of a female. But though small, it is a powerful jawbone. "In fact," he continues, "the essential character of this fossil is its robustness, if I may so express myself. The bone throughout is thick and stocky, and thus approaches much nearer the jaws of anthropoids than those of man. The chin, in lieu of projecting forward beyond the vertical line, inclines backward. It is something intermediate between the man and the monkey. The sockets of the teeth show that the molars, in place of diminishing from the first to the last, were developed in the opposite way. Finally, in the middle of the inner curve of the jaw, in place of a little excrescence called the 'genial tubercle,' there is a hollow, as with monkeys. We may, then, say that this human relic is the most pithecoid that has yet been found." The inference to be derived from this formation is thus set forth by our author: "Speech, or articulate language, is produced by movements of the tongue in certain ways. These movements are effected mainly by the action of the muscle inserted in the genial tubercle. The existence of this tubercle is therefore essential to the possession of language. Animals which have not the power of speech do not possess the genial tubercle. If, then, this tubercle is lacking in the Naulette jawbone, it is because the man of Neanderthal, the 'Chellean man,' was incapable of articulate speech."

It must not be supposed, from this brief description, that M. de Mortillet imagined that the genio-glossal muscle, the muscle which moves the tongue, and which in fact, as Prof. von Meyer states, contributes most to the form of that member, was lacking in the Chellean man, as it certainly is not lacking in the anthropoid apes. It is not the muscle itself, but the mode of its insertion, which is to be regarded. In the apes and other lower animals, where the tongue is mainly used to aid in taking, masticating, and swallowing food, much less freedom of motion is required for it than in man, for whom its chief use is in the many delicate movements required in framing the elements of articulate utterance. It is for this greater freedom that the insertion of the muscle — or rather of the muscles, for there are two of these — in the genial tubercle or tubercles (for

there are also two of these) is required. Or, to speak still more precisely, it should rather be said that it is by the incessant action of the muscles pulling on the bone in these varied movements, that the tubercles themselves must be deemed to have been developed. Such is the explanation given by the able anatomists whom I have consulted on this curious and important point.

It will seem that a single jawbone affords but scanty evidence on which to base so momentous a conclusion. But confirmation has not been wanting. In August, 1880, Professor Maschka found in the Schipka cave, in northeastern Moravia, among bones of the elephant, rhinoceros, and other animals of the pleistocene era, a fragment of a human jawbone, bearing a remarkable resemblance to that of the Naulette cave. Like the latter, it inclined backward at the chin, being in this respect intermediate between the jaw of the ape and that of the man; and, as in the Naulette jaw, the genial tubercle was wanting. The two jawbones have been submitted to a most careful and thorough scrutiny and analysis by Dr. Robert Baume, a distinguished writer on dentistry, who has brought out some novel and important points. He shows that, from the great backward inclination of the chin, the jaw must, when the mouth was open, have pressed upon the larynx and closed it entirely, unless the individual to whom the jaw belonged was of a much more prognathous type—or, in other words, had the lower part of the visage much more projecting—than is known in any now existing race. His conclusion is, that there lived in the diluvial or quaternary age races of men who were markedly inferior to the lowest races now existing. His view of the total disappearance of these ancient races, therefore, harmonizes entirely with that of Professor Dawkins.

This view is further confirmed by an examination of all the crania which are believed, on good grounds, to belong to this pristine people. These skulls are not numerous, but they are sufficient in number to characterize a race, and they are all of one cast. The Canstadt skull, the Neanderthal skull, the fragment of the Eguisheim skull and that of the skull found at Brüx in Austria, as well as the skull lately discovered at Podhava in Bohemia, all belong to this earlier race, and all show the same peculiar characteristics,— namely, a remarkable projection of the superciliary ridges, or the prominences just above the eyes, and an extremely low and receding forehead. What are termed the frontal promi-

nences, that is, the projections of the upper part of the forehead, are entirely lacking. In both these respects the skulls of this race unquestionably approximate to those of the higher order of apes, the orang, the gorilla, and the chimpanzee. Speaking of the Neanderthal skull, in his Lectures on "Man's Place in Nature," Professor Huxley says: "Under whatever aspect we view this cranium, whether we regard its vertical depression, the enormous thickness of its superciliary ridges, its sloping occiput, or its long and straight squamosal suture, we meet with ape-like characters, stamping it as the most pithecoid of human crania yet discovered." But he adds that the cubit capacity of the skull is about seventy-five inches, which is the average capacity given by Morton for Polynesian and Hottentot skulls, while the average capacity of the gorilla skull is only about one-third of that amount. Thus it is clear that the Neanderthal skull is that of a man, and not of an ape. But in these ancient crania the greater portion of the capacity is in the posterior part of the skull. The narrowness and depression of the forehead are remarkable, and exceed anything known in the skulls of existing races. The height of the forehead depends, of course, upon the development of the frontal lobe of the brain. The frontal lobe is made up, as regards its height, of three folds, or convolutions, termed by anatomists the first, second, and third frontal convolutions. These convolutions lie one above the other, the third being the lowest. This third convolution is somewhat thicker than the other two, and adds therefore, in general, somewhat more to the height of the forehead than either of the others. Its absence, or almost entire absence, from the brain, would produce just such a depression, or extraordinary flatness, as we find in the foreheads of these ancient skulls. Now it is a remarkable fact, that, while the brain of a monkey is much smaller than that of a man, its general outline is very similar to that of the human brain. As Professor Huxley says, "the brain of a monkey exhibits a sort of skeleton map of man's." Most of the convolutions which are found in the one are present in the other. But there is one remarkable exception. In the lower apes the third frontal convolution is, according to Hartmann, "entirely absent." In the higher or anthropoid apes, it appears, but only in a rudimentary form. "Its great development in men," writes Gewährsmann, "constitutes one of the most marked distinctions between the brains of apes and those of men." This statement has been

questioned, as there is some difference of opinion in regard to the analysis of the convolutions; but Bischoff, the highest authority, confirms it; and Professor Hovelacque, in an article recently published in the *Revue Scientifique* on "The Evolution of Language," repeats the statement in these significant words: "We mention here, without dwelling upon it, that the faculty of language stands in close relation with a certain one of the frontal convolutions of the brain, which the inferior monkeys do not possess, and which is found in a rudimentary state in the anthropoids, but of which the full acquisition and most complete development have made man what he is, the master of articulate speech."

This third frontal convolution is sometimes called "Broca's convolution," from the fact that the distinguished French physiologist, Dr. Paul Broca, was the first to localize the faculty of language in it. This faculty, according to the description given by Dr. Topinard in his "Anthropology," has its seat in "the posterior portion of Broca's third frontal convolution." "Its surface has a vertical height of about four centimeters" (or a little over an inch and a half), "and an antero-posterior extension of from two to three and a half centimeters," that is, from a little less than an inch to nearly an inch and a half. Any lesion or disease of this part of the brain, as is well known to medical men, produces aphasia, or the loss of the power of speech. If this convolution were absent from the human brain, or were only present in a rudimentary form, as in the anthropoid apes, the man would be incapable of speech, and the height of his forehead would be greatly diminished. We should have, in fact, the precise difference which exists between the frontal portion of the Neanderthal or Podhaba skull, and that of the average skull of the present race of men.

Some eminent writers, and one who may justly be styled preeminent, M. de Quatrefages, have sought to show that in modern times skulls similar to those of this ancient race have been met with, and in some cases have belonged to persons of no mean intellectual capacity. In his admirable work on "Fossil Men and Savage Men," he gives pictures of the skulls of St. Mansuy, Bishop of Toul, and of a Danish gentleman, named Kai-Likké, who took some part in politics in the seventeenth century. These are compared with the Neanderthal skull. The measurements are not given, but their outline, and especially the front view of the Kai-Likké cranium, show a distinct superiority in height to the Nean-

derthal skull; and we must remember that an ecclesiastic or a politician may have but a scant development of the faculty of language, and may yet gain distinction by other intellectual qualities.

The man of the River-drift, this Canstadt or Chellean man, was widely dispersed over a considerable part of the globe. His presence is known by the peculiar implements, or rather implement, which he fashioned; for, in reality, as Prof. de Mortillet shows, he had but one, though this appears in varying shape. It is called, among writers on this subject, by different names. Some speak of it as an axe, others simply as the "drift implement," and M. de Mortillet describes it as "a stone fist." It is, in fact, simply a stone chipped rudely into an ovate or almond-like shape, such as would enable a man to grasp it at one end, and strike with it a more effective blow than he could strike with his naked fist. It could be used in this manner for striking, scraping, or pounding, and, in a rough way, for cutting. There is a singular rudeness in its appearance, which marks at once the low intellectual grade of those who fashioned and used it. Dr. Daniel Wilson, in his work on "Prehistoric Man," has some striking remarks on this subject. He observes (in his third chapter) that the investigator, in examining the earliest palæolithic implements, might imagine that he had "traced his way back to the first crude efforts of human art, if not to the evolutionary dawn of a semi-rational artificer. It is a significant fact," he continues, "that no such clumsy unshapeliness characterizes the stone implements of the most degraded savage races." And he adds, that this essential difference of type "seems to point to some unexplained difference" between the artificers of the two periods. The explanation of this difference, which struck and perplexed this most discerning observer, seems now to be found in the fact that the earlier implements were the production of beings whose minds were in the undeveloped state that must necessarily characterize men who had not yet attained the power of speech. No one will question the justice of Professor Whitney's remark on this point: "The speechless man is a being of undeveloped capacities, having within him the seeds of everything great and good, but seeds which only language can fertilize and bring to fruit; he is potentially the lord of nature, the image of his Creator; but in present reality he is only a more cunning brute among brutes." "A man born dumb," observes Professor Huxley, "notwithstanding

his great cerebral mass and his inheritance of strong intellectual instincts, would be capable of few higher intellectual manifestations than an orang or a chimpanzee, if he were confined to the society of dumb associates." We need not therefore be surprised to find that, wherever traces of the River-drift men have been discovered, whether in France, England, Greece, Asia Minor, India, North Africa, or America, these traces, which consist merely of their peculiar implements, are everywhere the same, showing no variety in different regions, and no apparent improvement during the lapse of ages. The drift implements which the fortunate and skilful researches of Dr. Abbott have disclosed in New Jersey are in shape exactly like those which earlier investigators had unearthed from the river-banks of France and England.

In view of these and other discoveries indicating the existence of palæolithic man in America, and also in view of other facts relating to the fauna of the two hemispheres, M. de Mortillet is decidedly of opinion that during a considerable portion of the early quaternary era a connection existed between Europe and America by way of the Faroe Islands, Iceland and Greenland. It is well known that such a connection existed during the miocene era. It was broken up in the pliocene age. But, as we know, a vast elevation of land in Europe took place during the glacial epoch of the quaternary or pleistocene age. The facts adduced by Professor Boyd Dawkins, in his "Early Man in Britain," show that, if this elevation attained the height of five hundred fathoms, it must have restored the connection between the two continents. He also shows that the elevation did actually reach, at least in the region of the Mediterranean, a height of at least four hundred fathoms. An additional rise of a hundred fathoms in the north, which may well be supposed, would have restored the "great tertiary bridge," and enabled the River-drift man, with the various other animals of his epoch which are found on both continents, to pass from one to the other.

But when the next race, which is styled by M. de Quatrefages the race of Cro-Magnon, appeared, the connection between the two continents had long ceased to exist. The great ice age had passed away, and Europe was assuming its present condition. This race of Cro-Magnon offered, in some respects, the strongest possible contrast to the preceding race of Canstadt, or River-drift men. In physical development it was, to use the expression of this distin-

guished writer, "a magnificent race." The skull is large and well developed, with a forehead at once wide and lofty. The capacity of one of these crania, according to Broca's measurement, was not less than 1,590 cubic centimeters, which exceeds by 119 centimeters the average size of Parisian skulls of the present day. "Thus," adds M. de Quatrefages, "in this savage, a contemporary of the mammoth, we find all the craniological characters generally regarded as the signs of a great intellectual development." To this may be added, that in the earliest lower jaw of this race which has been discovered the genial tubercle is fully developed. The man of this epoch was a social being, endowed with the faculty of speech. His frontal lobe was large and high, and every convolution of the brain must have existed in unusual size. His intellectual powers corresponded with this development. Of this fact we have the most remarkable and indeed astonishing proof in his works of art, — his pictures engraved on pieces of stone, ivory, and bone, and his sculptures in bone and ivory. His representations of the animals of that period — the mammoth, the reindeer, the elk, the bear, the horse, the urus, the chamois, the whale, the pike, and many others — are most admirable for the artistic skill which they display, and for their evident truth to nature. On this point all observers are agreed. "We recognize in them," writes M. de Mortillet, "the works of a people eminently artistic. In these primitive engravings and sculptures we remark so true a sense of form and movement that it is almost always possible to determine exactly the animal represented, and to perceive the intention of the artist. Some of the works are really small masterpieces." "So natural are the attitudes, so exact the proportions," writes M. de Quatrefages, "that a decorative sculptor of our own days, in treating the same subject, could hardly do better than to copy his ancient predecessor." Dr. Wilson speaks in the highest terms of the "skill and intellectual vigor" manifested in these works of art, and adds the noteworthy remark: "In truth, it is far easier to produce evidences of deterioration than of progress, in instituting a comparison between the contemporaries of the mammoth and later prehistoric races of Europe or savage nations of modern centuries." In short, the evidence is clear and unquestionable, that, while the earliest race, the River-drift men, were in form and intellect the lowest race of human beings that have ever existed, their immediate successors, the Cave-men, or race of Cro-Magnon,

must be ranked, in shape and aspect, in cranial development, and in intellectual endowments, among the very highest.

It is proper to observe, that M. de Mortillet and Professor Dawkins make a distinction between the Cave-men and the "Neolithic men," or men of the Polished Stone era, who immediately followed them; and they ascribe the remains of Cro-Magnon to the latter race. M. de Mortillet admits, however, that the people of Cro-Magnon were "evidently descendants of the Magdalenians," or Cave-men, who wrought these works of art; and Professor Dawkins shows that the art-loving Cave-men and the less artistic Neolithic population were at one time contemporaries. It should be added, that the fact that this artistic race lived at the same time with the mammoth, which is now extinct, affords no evidence of its great antiquity. The mammoth was merely a variety of the elephant, differing so little from the existing varieties that some naturalists have refused to consider it a distinct species. It probably became extinct at a quite recent period. Another extinct mammal, the great Irish elk, which was hunted both by the Cave-men and by the Neolithic men, survived down to the Bronze age; and the urus, another animal of the quaternary era, only became extinct a few centuries ago. The Cave-men of Professor Dawkins, the Cro-Magnon race of Prof. de Quatrefages, were really a modern people, — a people of our own age. And the question naturally arises, When did this age, the age of speaking man, commence? The answer will doubtless surprise many persons who have been accustomed to consider the question without regard to the primary and all-important distinction between the two races of men,— the speechless and the speaking race. The former can, no doubt, be traced back to an immense and undefined antiquity. The appearance of the latter dates back probably less than ten thousand years.

We might feel tolerably sure of this fact, as a conclusion of simple reasoning. It is impossible to suppose that a people possessing the intellectual endowments of the Cro-Magnon race would remain long in an uncivilized state, if they were once placed in a country where the climate and other surroundings were favorable to the increase of population and to improvement in the arts of life. Even in the then rigorous climate and other hard conditions of Western Europe, they had advanced, as Dr. Paul Broca declares, "to the very threshold of civilization." What must they have

become in Egypt and in Southern Asia? In point of fact, during a comparatively brief space of time, ranging from five thousand to seven thousand years ago, the men of these regions developed in widely distant centres — in Egypt, in Mesopotamia, in Phœnicia, in Northern India, and in China — a high and varied civilization and culture, whose memorials, in their works of art and their literature, astonish us at this day, and in some respects defy imitation. To what circumstance can we attribute this sudden and wonderful flowering of human genius, after countless ages of torpidity, but to the one all-sufficient cause,—the acquisition of the power of speech? Many skilled observers have sought to discover by various indications, such as the accumulation of débris in caves, the layers of earth formed by streams, the growth of bogs, and other evidences, the time which has elapsed from the era of the Cave-men and the Neolithic race to our own time. Professor Dawkins, in his account (given in his work on "Cave-Hunting") of the exploration of the Victoria Cave, at Settle in Yorkshire, makes an estimate, from the accumulation of talus in the cave, of the time which has elapsed since the cave was occupied by Neolithic man, and fixes it at about 4,800 or 5,000 years. Many other investigators have reached similar results. Their conclusions are well summed up by Prof. Alexander Winchell, in his work entitled "Preadamites." "Morlot," he tells us, "from the study of the layers constituting the 'cone of the Tinière,'— a deposit formed by a torrent discharging itself into the Lake of Geneva,— concluded that the Polished Stone epoch dates back 4,700 to 7,000 years. Gillieron, from researches at the Bridge of Mièle, is led to fix the epoch of Polished Stone at 6,700 years. Steenstrup, from investigations in the bogs of Denmark, is led to regard 4,000 years as the minimum for that epoch. De Ferry, from a study of the river-drifts of the Saône, puts the Polished Stone epoch at 4,383 years, and the epoch of the mammoth at 5,844 to 7,305 years,—"fortunate," adds Professor Winchell, dryly, "if the thousands are as exact as the units in these figures." Arcelin, he further tells us, from a separate study of the drifts of the same river, arrives at a very close agreement with De Ferry, putting the epoch of Polished Stone from 3,000 to 4,000 years back, and the blue clay, containing the mammoth, from 6,700 to 8,000 years. Finally, Le Hon, in view of all the results, fixes the age of Polished Stone at from 4,000 to 6,000 years, the age of the reindeer (which is in fact the age of Professor Dawkins's Cave-men) at a point

beyond 7,000 years, and carries back the age of the mammoth to an indefinite period. All these estimates are in substantial accord; and none of them place the appearance of the Neolithic race, or men of the Polished Stone epoch, earlier than seven thousand years, or that of the Cave-men, or men of the Reindeer period, more than eight thousand years back. The terms in each case are as likely to be less than these numbers as they are to be greater. It is impossible not to yield assent to such a mass of concurrent evidence.

If a pair of human beings, male and female, endowed with speech and possessing the faculties of the earliest known people, the Cro-Magnon race, appeared in some region of the old continent where the climate and the natural productions were favorable to the existence of men, what time would be required for their descendants to become numerous enough to found the early communities of Egypt and Mesopotamia, and to spread into Europe and Eastern Asia? The question is easily answered. Supposing the population to double only once in fifty years, which is a very low estimate, it would amount in twelve hundred years to about forty millions, and in fourteen hundred years would be over six hundred millions, or nearly half the present population of the globe. That less than a thousand years will suffice to create a high civilization, the examples on our own continent presented by the Mexicans, the Mayas, the Muyscas, and the Peruvians amply prove. And that the same space of time would be sufficient for the development of the physical peculiarities which characterize the various races of men, by climatic and other influences, is made clear by the evidence accumulated by Prichard, De Quatrefages, Huxley, and other careful and trustworthy investigators. Nor need the change of climate which was undoubtedly in progress during the earlier part of the existence of the Cro-Magnon race, and which is believed to have contributed to the extinction of the mammoth and other animals of that era, have occupied a longer period. In fact, the observations and estimates just quoted from Professor Winchell seem to show clearly that it did not. If the diversity of languages has had its origin in the cause suggested in this essay, and may therefore have arisen in any period, however brief, during which the peopling of the world has proceeded, there would seem to be no grounds whatever for referring the first appearance of speaking man to a greater antiquity than eight, or at the most ten, thousand years.

How, and where, did this momentous apparition occur? These are questions which naturally arise, and our inquiry would not be complete without a brief consideration of them. That the "speaking man" of our era is a descendant of the "speechless man" of the River-drift period cannot be doubted. We have not to deal with the origin of a new species, but simply with that of a variety. There can be no question that this variety arose in the usual way, by what is termed the process of heterogenesis, or, in other words, the law by which the offspring differs from the parents. As every child has two parents, it cannot resemble both, and, in point of fact, it never exactly resembles either of them. Ordinarily, this unlikeness is restricted within certain defined and rather narrow limits; but occasionally, as when dwarfs or giants are born to parents of ordinary stature, it is very great. Among the lower animals, when such offsprings propagate their like, a new variety or breed arises, which sometimes differs very widely from the original stock,— as occurred, for example, in the Ancon or otter breed of sheep, which thus originated in New England, and in the hornless cattle which have overspread several provinces of Paraguay. That in some family of the primitive speechless race two or more children should have been born with the faculty and organs of speech is in itself a fact not specially remarkable. Much greater differences between parents and offspring frequently appear. Among these, for example, is one so common as to have received in physiology the scientific name of polydactylism, a term applied to the case of children born with more than the normal number of fingers. M. de Quatrefages mentions that in the family of Zerah Colburn, the celebrated calculator, four generations possessed this peculiarity, which commenced with Zerah's grandfather. In the fourth generation four children out of eight still had the supernumerary fingers, although in each generation the many-fingered parent had married a person having normal hands. Plainly, he adds, if this Colburn family had been dealt with like the Ancon breed of sheep, a six-fingered variety of the human race would have been formed; and this, it may be added, would have been a far greater variation than was the production of a speaking race descending from a speechless pair. The appearance of a sixth finger requires new bones, muscles and tendons, with additional nerves leading ultimately to the brain. There is good reason to believe that the first endowment of speech demanded far less change than this. All the an-

thropoid apes can utter cries of some sort, and some of them can make a variety of sounds. Professor Hartmann expressly informs us that the larynx in these animals resembles in the main that of man. We cannot doubt that our primitive ancestor, the *Homo alalus*, in spite of his name, could utter many sounds, and possessed the usual vocal organs. Professor Huxley has dwelt with much force on the slight anatomical difference which might exist between the speechless and the speaking man. A change of the minutest kind, he tells us, in the structure of one of the nerves which communicate with the vocal chords, or in the structure of the part in which it originates, or in the supply of blood to that part, or in one of the muscles to which it is distributed, might render all of us dumb. And he adds (in words similar to those already quoted: "A race of dumb men, deprived of all communication with those who could speak, would be little indeed removed from the brutes. The moral and intellectual difference between them and ourselves would be practically infinite, though the naturalist should not be able to find a single shadow even of specific structural difference."

In the actual case, so far as can be judged from the osteology, the changes which took place when the speaking children were born to the speechless pair were in the greater development of the cerebral convolution in which the faculty of language resides, in the new direction given to the under part of the lower jaw, which now projected forward instead of receding, and in the increased volume and strength of the genio-glossal muscles, which by their action developed the genial tubercle, and gave at once greater size and more freedom of movement to the tongue. These changes, though so important in their results, were really slight compared with the changes in a case of polydactylism. The chief alteration was, of course, that which took place in the brain. It was simply the enlargement of a fold of that organ; but its effect was prodigious, and has transformed the globe. This enlarged fold was the seat, not merely of the faculty of language, but of many other faculties, all of which showed at once the effect of their newly acquired power.

And here it is proper to remark on the mistake, or the confusion of processes, which has led some esteemed writers to suppose that the first speaking men, originating from parents of weak mental capacity, must have partaken of that intellectual feebleness. Elaborate works have been written on this subject, in which the whole

argument has been based on the supposition that the earliest of speaking men were inferior to their successors, not merely in accumulated knowledge,—which was a matter of course,—but in mental power, which is a very different affair. The lowest tribes of our time — the Australians, Hottentots, Fuegians, and other savages — have been assumed to be fair representatives of what our earliest ancestors must have been when they were first endowed with the faculty of speech. This supposition is contrary both to reason and to the known facts. It confuses two processes, which are totally unlike in their working and in their results. The changes caused by climate and the other external influences which are commonly known as the "environment" are gradual. The changes which arise from heterogenesis are sudden, and are at once complete. In the cases of polydactylism, we do not find that a mere germ or stump of a finger first appears, and gradually becomes longer and stronger in succeeding generations. The perfect finger appears at once. So in the lower animals: the Ancon or otter breed is known to have sprung from a single sheep, born with abnormally short legs, which became no shorter in its descendants. The hornless cattle of Paraguay are known to be all descended from a single animal, which was born without horns. There is no reason for supposing that the earliest speaking men may not have been endowed with the highest intellectual faculties of the human race. There is every reason to believe that they were so endowed. The race of Cro-Magnon, the earliest known race of social men, though barbarians, were, in point of cerebral development and of artistic powers, not only superior to any barbarians of the present day, but certainly equal, if not superior, to any civilized race that has ever existed. The other earliest communities known to us, those of Egypt and of Southwestern Asia, have surpassed in their architecture and their inventions all succeeding races. Their temples and other structures are the despair of our architects. All the first elements of knowledge and of progress have come from them. They invented pottery and glass, the plough and the loom. They invented the alphabet, and with it a varied and voluminous literature. They invented astronomy, geometry, and history. They smelted copper and iron. They tamed almost all the most useful animals. They first cultivated almost all the most valuable esculents. They and their earliest offshoots devised all the forms of settled government,— monarchy in Assyria and Egypt, theocracy

in India, aristocracy in Phœnicia, and democracy in Arabia. They invented the great Egyptian, Assyrian, and Aryan religions, and endowed their gods with the qualities of knowledge, power, and justice, which they most admired in their rulers. In Egypt they instituted the judgment after death, and in Assyria they established the Sabbath. Their period was that which has been well styled by Mr. Gladstone the "youth of the world,"—*juventus mundi*,— when the human race, on its thinly peopled planet, felt all its energies called forth to meet the wants and solve the problems of its new existence.

This conclusion as to the high intellectual grade of the earliest speaking man is very important in its bearing on our views respecting the so-called inferior races. It is clear that they represent, not this primitive man, but simply a degeneration caused by unfavorable influences. If this degeneration has taken place, as there seems every reason for believing, within a very brief period,—five or six thousand years at furthest, and most of it probably within a few centuries after their separation from the original stock,— there seems good reason for believing that an improvement in their surroundings will be followed by a gradual elevation, and a return to the high primitive type.

The question of the region in which speaking man first appeared is one on which there is room for a wide difference of opinion. It is a question about which no one will venture to dogmatize. The natural supposition, of course, would be that this first appearance took place somewhere near the centres of the earliest civilization. These centres were in Egypt and Assyria. Between those countries lies Arabia, in which, amidst the sand desert that protects the land from invasion, there are many oases, large and small, blessed with a most genial climate and a fruitful soil. In these oases, which have never known the sway of a foreign conqueror, the native traditions go back to a dim antiquity, in which no evidence of early barbarism is discerned. From that primitive centre, if such it was, the increasing population would speedily overflow into the plains of Mesopotamia and the fertile valley of the Nile; and there, or in their near vicinity, nearly all the animals which were first tamed, and nearly all the plants which were first cultivated, would be found. We need not be surprised, therefore, to find that the great majority of investigators have looked to Southwestern Asia for the primitive seat of the human race. The most

distinct tradition that has come down to us of the earliest belief respecting the creation of man — the tradition which is preserved in the Hebrew narrative — places it in an oasis on the Arabian border, and dates it apparently at about the time when, as all the evidence seems to show, man endowed with speech first appeared.

One other question, not certainly of the first importance, but still of curious and genuine interest, remains to be considered. If the first language spoken by man was invented less than ten thousand years ago, it may be deemed next to a certainty that this language has survived to our time,— not, of course, in its exact original form, but in some derived idiom. It may be taken for granted that the population speaking this language would be widely diffused, and would have many descendants, now speaking affiliated languages of the original stock. There are three families of languages clustered about the supposed centre of this priscan population, the Hamito-Semitic, the Aryan, and the Ural-Altaic. The Hamito-Semetic stock has for its earliest representatives the Arabic, the Assyrian, the Hebrew, and the Egyptian. The Aryan family numbers among its most ancient members the Sanscrit, the Zend and the Greek. The Ural-Altaic stock, to which the Turkish, the Finnish, and the Hungarian languages belong, finds its chief, but sufficient, claim to high antiquity in the Accadian, whose discovery and decipherment, from the hieroglyphics of the Assyrian inscriptions, have furnished one of the most notable triumphs of modern scholarship. Each of these three great families of speech is very widely diffused, and each of them might advance strong claims to this curious genealogical distinction of being the direct representative of the earliest tongue. The question is one whose determination by strictly scientific methods does not seem by any means beyond reasonable hope. If science can weigh the planets, can define the chemical components of the fixed stars, and describe the shape of continents that existed millions of years ago, it may surely be expected to find evidence for determining the particular linguistic stock to which the earliest spoken language belonged. Such evidence as we have at present certainly seems to favor the Hamito-Semitic family. This family possesses the most ancient literature, and, if the difference between the Hamitic and Semitic groups is considered, seems to have varied, in the long lapse of ages, must widely. Lepsius and F. Müller have traced its influence far into the interior of Africa; and Professor Gerland, going further still, unites the whole popu-

lation of that vast peninsula with the Semitic group in one great Arabic-African race. There is a certain evidence — not perhaps decisive, but worthy of consideration — which seems to connect the Cro-Magnon race with the Hamitic branch of this family. The extinct population of the Canary Islands, the Guanches, are known to have belonged to this Hamitic branch, and their crania, as Prof. de Quatrefages shows, bear a striking resemblance to those of the men of the Cro-Magnon era. This cautious investigator does not hesitate to pronounce the Guanches to be evidently the descendants of that ancient race. He declares that "the resemblance of cranial forms sometimes amounts to identity," and he adds the confirmatory fact, that a late observer, M. Verneau, has found among the present islanders — who are in part descended from the Guanches — implements precisely like those which were used in France by the Cro-Magnon hunters.

The conclusions to which this inquiry, guided by the most recent discoveries of science, has directed us, may be briefly summed up. We find that the ideas of the antiquity of man which have prevailed of late years, and more especially since Lyell published his notable work on the subject, must be considerably modified. No doubt, if we are willing to give the name of man to a half-brutish being, incapable of speech, whose only human accomplishments were those of using fire and of making a single clumsy stone implement, we must allow to this being an existence of vast and as yet undefined duration, shared with the mammoth, the woolly rhinoceros, and other extinct animals. But if, with many writers, we term the beings of this race the precursors of man, and restrict the name of men to the members of the speaking race that followed them, then the first appearance of man, properly so styled, must be dated at about the time to which it was ascribed before the discoveries of Boucher de Perthes had startled the civilized world,— that is, somewhere between six thousand and ten thousand years ago. And this man who thus appeared was not a being of feeble powers, a dull-witted savage, on the mental level of the degenerate Australian or Hottentot of our day. He possessed and manifested, from the first, intellectual faculties of the highest order, such as none of his descendants have surpassed. His speech, we may be sure, was not a mere mumble of disjointed sounds, framed of interjections and of imitations of the cries of beasts and birds. It was, like every language now spoken anywhere on earth by any tribe, how-

ever rude or savage, a full, expressive, well-organized speech, complete in all its parts. The first men spoke, because they possessed, along with the vocal organs, the cerebral faculty of speech. As Professor Max Müller has well said, "that faculty was an instinct of the mind, as irresistible as any other instinct." It was as impossible for the first child endowed with this faculty not to speak, in the presence of a companion similarly endowed, as it would be for a nightingale or a thrush not to carol to its mate. The same faculty creates the same necessity in our days; and its exercise by young children, when accidentally isolated from the teachings and influence of grown companions, will readily account for the existence of all the diversities of speech on our globe.

If the views now presented shall be confirmed by further investigations, they will serve to clear up uncertainties which have perplexed the minds of students of linguistic science and of archæology, and have seriously impeded the progress of all the anthropological sciences. The views, with the evidence which seems to sustain them, are therefore respectfully submitted to the candid consideration of the members of our Section, and through them to the students of those sciences in other countries, in the hope of inducing further inquiry which may lead to decisive and satisfactory conclusions on these important questions.

PAPERS READ.

PRELIMINARY NOTE OF AN ANALYSIS OF THE MEXICAN CODICES AND GRAVEN INSCRIPTIONS. By ZELIA NUTTALL, Peabody Museum, Cambridge, Mass.

I WISH to make a statement of a few of the results I have recently obtained by a translation into the Nahuatl language of the phonetic symbols contained in the Vienna Codex and the Selden and Bodleian MSS. I find that these entire Codices are composed of signs representing parts of speech forming, in combination, words and sentences. Moreover I have discovered certain determinative signs that render a misinterpretation of these picture writings impossible. The Vienna Codex and the Bodleian and Selden MSS. are records of lands, tributes, tithes and taxes. A partial decipherment of portions of the Borgian, Vatican and Féjéroary Codices convinces me that these do not relate, as has been supposed and maintained, to astrological and exclusively religious matters, but deal with the details of a communal form of government, the existence of which has been suggested by some recent writers but not sufficiently proved to be generally accepted.

The as yet imperfect insight I have obtained through these native works confirms and completes much of the testimony of the early Spanish writers, but also renders evident the false and distorted impressions they received and handed down.

Familiarity with certain phonetic symbols of frequent recurrence in the picture-writings caused me to perceive, somewhat to my astonishment, that identical symbols are reproduced on the so-called "Calendar Stone," the "Sacrificial Stone" and other equally well known monoliths. Through the decipherment of these and an application of the same method to other symbols engraved thereon, I unhesitatingly affirm, even at this early stage of investigation, that these graven monoliths are not what they have hitherto been considered. On them are Nahuatl words that are found in the Codices, in Sahagun's invaluable Historia, and in other early chronicles, where imperfect explanations of them are given, and these words reveal beyond doubt the true uses and purposes of the Stones.

Let us cursorily examine the testimony of the best authorities on a certain point.

Duran tells us distinctly that there was, in each market-place of Ancient Mexico, a circular, elaborately carved tablet, held in great veneration. It was frequently consulted and by it the market-days were regulated.

All writers concur in stating that the market was held on each fifth day. According to them a period of five days answered to our week, and four

such divisions formed the period of twenty days termed the Mexican month.

They tell us that all adults were obliged by law to resort to the appointed market place on each fifth day, and that all produce and manufactures had to be brought there, even from great distances, severe penalties being incurred by those who bartered the produce of land or labor, on the highway or elsewhere. On the broad, straight, cemented roads leading to the locality of each market, "resting places" for the wayfarers and carriers were provided, at regular intervals, and by the number of such stopping-places between one point and another, distances were estimated. The enormous concourse of people, the variety of produce exhibited, and the order that prevailed in the markets of Mexico and Tlatelolco filled the Conquerors with wonder and admiration. From Cortes, Bernal Diaz, Sahagun and others, we learn that the market was a special charge of the supreme chief of Mexico; that appointed officers presided in state over it, while others moved among the throng superintending the traffic. Standard measures were kept and rigorous punishment awaited those who sold by false measure or bartered stolen goods.

It is my opinion, and one that I can support by a mass of further corroborative evidence, that the periodical market day was the most important regulator of the Mexican social organization, and that the monolith known as the Calendar Stone was the *Market Stone* of the City of Mexico. It bears the record of fixed market days, and I venture to suggest that from these the formation of the Mexican calendar system originated. The stone shows the existence of communal property and of an equal division of general contribution into certain portions.

I find, moreover, that the face enclosed in the inner circle of the tablet is a rebus. When its several parts are interpreted by the phonetic elements they represent, a sentence is obtained which clearly shows the use of the tablet. Of this sentence I shall submit but two words, deeming these sufficient, for the present, to prove my method and its results.

Thus from the phonetic elements:

tetl = stone
ixtli = face or surface
pan = upon

is obtained by combination, according to rules of the Nahuatl grammar, the word *teixpan*, meaning "publicly." In Molina's dictionary, the noun *teixpanca* is translated as: "something evident and manifest to all."

The protruding tongue yields the two elements of the word *nenepilquiça* = to mark, "note, keep account of," formed by *nenepilli* = tongue, and *quiça* = to go out.

These statements are, of course, almost meaningless to any but Nahuatl students, acquainted with the pictographic system.

Now, turning to the monolith generally known as the Sacrificial Stone, I find it to be a *Law Stone* of similar nature, recording the periodical collection of certain tributes paid by subjugated tribes, and others whose obligation it was to contribute to the common wealth of Mexico.

A symbolic frieze around the stone consists of four groups, placed at intervals, of flints = *tecpatl*, with conventionally carved teeth = *tlantli*, giving, in combination, the word *tecpatlantli*. This word occurs in Sahagun's Historia as the name given to the "lands of the palace;" and in one of the native works, I find designated the four channels into which the produce of these lands was diverted. The periods indicated on it differ from those on the great market stone, and seem to furnish a solution to the perplexing complementary calendar system mentioned by Spanish writers as the "lords of the night accompanying the days."

In conclusion I will state that, in my opinion, many of the large stone receptacles which are generally called "vessels for containing the hearts and blood of human victims," are the standard measures, kept for reference in the market place.

Before publishing my final interpretations and results, I shall submit them to a searching and prolonged investigation. An examination of the originals of many of the codices reproduced in Lord Kingsborough's Mexican Antiquities will be necessary to determine important points, and during the coming year my line of research will be in this direction.

THE PHONETIC ELEMENTS IN THE GRAPHIC SYSTEMS OF THE MAYAS AND MEXICANS. By DR. DANIEL G. BRINTON, Media, Penn.

[ABSTRACT.]

IT is acknowledged by all that the tribes in Yucatan, known collectively as the *Mayas*, and those in Mexico included under the titles *Nahuas*, *Aztecs* or distinctively *Mexicans*, made use of a graphic system or systems; but it has been asserted even by recent authorities that these systems had no phonetic elements, and were wholly representative, pictographic or ideographic. That they are partly or even largely of this character, no one will deny; but that they also possess numerous distinct phonetic elements, and that only by interpreting these through the sound of the languages can the writing be read, are facts which accumulating evidence forces upon our acceptance.

The phonetic element in a language may consist of whole words, of syllables, or of single sounds or letters; or all of these may be present simultaneously along with ideograms and pictures. Both the MAYA and MEXICAN graphic systems are of this last mentioned composite character. The Maya has been especially studied by Thomas, Förstemann and Schellhas, all of whom recognize that it presents a certain number of true phonetic characters; and the fact that none of these investigators had a knowledge of the Maya language is a reason why their researches in this direction yielded limited results.

The Mexican graphic system has been much more thoroughly studied than that of the Mayas, and its phonetic principles are better understood.

The Nahuas had symbols for the expression of four or five individual letters, many separate monosyllables, and various dissyllables. Their system was originally developed out of that of the rebus, and cannot be interpreted by one unacquainted with the language as spoken.

The early missionaries succeeded in framing a complete alphabet on the phonetic system of the Mexicans, but it was not until the researches of Aubin that an extension of it to the interpretation of existing monuments was attempted. Although nearly forty years have passed since the appearance of Aubin's memoir, no positive advance has been made in the application of the principles he laid down. The reason of this is obvious—none of the scholars who have turned their attention in this direction have prepared themselves by a careful study of the Nahuatl language. Without this, it is clearly impossible to ascertain the significance of signs which refer to the sounds of words or syllables. An illustration of the great success which will attend earnest studies of the codices when enlightened by a knowledge of the tongue is shown by the results obtained by Mrs. Zelia Nuttall. (These results were briefly stated, and the character of the phoneticism in the Maya and Mexican pictography explained by copies of phonetic symbols.)

ADDITIONAL OBSERVATIONS ON ANCIENT METHODS OF ARROW-RELEASE. By Prof. EDW. S. MORSE, Salem, Mass.

[ABSTRACT.]

THE author gave the final conclusions reached in regard to the persistence of arrow-release among certain races, and that all the methods of release were in existence in the earliest historic times.

[His paper is printed in full in the Bulletin of the Essex Institute.]

CHARACTERISTIC CURVES OF COMPOSITION. By Prof. T. C. MENDENHALL, Washington, D. C.

[ABSTRACT.]

THIS paper gives the results of a preliminary study of certain peculiarities of the vocabularies of well-known authors. By the classification of words according to the number of letters which they contain, and making a graphical construction, of the results it is believed that every author will be found to exhibit what may be called a "curve of composition," characteristic of and peculiar to him. It is suggested that this affords a method of detecting identity of authorship which is *purely mechanical* in its character, and hence certain in its results.

NOTES UPON A NATIVE BRAZILIAN LANGUAGE. By Prof. JOHN C. BRANNER, Indiana University, Bloomington, Ind.

[ABSTRACT.]

IN the little-explored parts of Brazil are many tribes of natives that have never come in contact with civilization. And yet, in the main, the dividing line between the Brazilians of European origin and the original inhabitants is rapidly disappearing.

Near the coast and along the Amazon and its readily navigable tributaries, the native tribes are rapidly losing their identity and their old customs, and adopting those of the Europeo-Brazilians. With these tribes their language must also disappear. I have frequently met and conversed with these natives, and have even had them in my employ for months at a time, but I have seldom had an opportunity of learning anything of their languages. Sometimes they were extremely uncommunicative, even after two or three months' acquaintance; at other times their knowledge of the Indian language was evidently too imperfect to permit me to feel any confidence in information obtained from them, and again their knowledge of the Portuguese would be too imperfect to enable me to converse with them readily.

At Aguas Bellas, in the interior of the province of Pernambuco, I once met for an hour only, a native belonging to one of these rapidly disappearing tribes, who spoke Portuguese fluently, and was more communicative than such people usually are. He was an old man, sixty or more, though bright and active, and upon occasion acted as interpreter for members of his tribe. I regret exceedingly that, having met him in the evening, when upon a long and tiresome journey, I was not able to obtain further notes from him concerning his language and his people.

The Brazilians at Aguas Bellas call these Indians the Carnijós. The Indians call themselves, that is, this tribe, in their own language, *Fŏ́rniŏ*, while Indians as distinguished from other people, are called *Iacotóa*.

There are several sounds in this language that do not occur in the Portuguese, and several that we do not have in English. For example, they have the sound of the German *ch*, English *th*, *u*, *w*, *h*, none of which belong to the Portuguese, and it is possible that there are others which my ear did not detect. My informant told me that my own pronunciation of their language was much better than that of the Brazilians, which is to be attributed to the absence of many of the sounds from the Portuguese language.

I can vouch for the accuracy of the few words given, as far at least as my ear could detect their forms, for they were repeated by me after my informant until he assured me that I had caught the correct pronunciation.

The numbers run only to ten; everything beyond that is many.

It will be noticed that this language seems to have a dual number, and that it makes a grammatical distinction between an object belonging to the speaker and one belonging to another person; for example, see the words for *my eyes*, *another's eyes*, and *two eyes*. The combinations made with the word for *hand* are also interesting.

It will be noticed also, in the case of the sentence given, that the object of the request is placed first.

I would call attention to the absence of the labials in these words, though of course this may be due to the small number given. To me this suggests that these Indians formerly used lip ornaments, such as are now used by Botocúdus, and which would render it impossible or very inconvenient to pronounce the labials.

Among the published works upon the native languages of Brazil, I have not been able to find any of these words.

On account of its simplicity, I have used the Portuguese spelling wherever it is possible.

Itó = my eyes.
Ató = another person's eyes.
Tocáno = two eyes.

Deretá = my nose.
Aretá = the nose of another.

Dutchí = my mouth.
Aotchí = another's mouth.

Jaxí = my tooth.
Axí = another's tooth.
Huatór = one.
Jaxí huatór = all my teeth, my whole set of teeth.

Taláw = horse.
Tskŭ́h = cow.
Refeitiŭ́h = cattle.

Tóch = fire.
Tātchá = firewood.

Tchó = the hand.
Tchó tchá = the lower arm.
Tchá fuá = the whole arm.
Tchó túlli = all the fingers.
Tchó kŭ = the little finger.
Tchó sŭ = the thumb.

D'hṓ hṓ = the breast, bosom.
Ichitá = the belly.
(Ich in this word has the sound of the German *Ich*.)
Sēĭ ku = food.
Ōŭ tchí = meat.
Kí tchí ŭ́h = *farinha*.
Tōkŭh = salt.
Óyĕ = water.
Óyĕ tĕ́hn í tíchina = give me some water.

PIUTE HERBALISTS. By Dr. CHARLES P. HART, Wyoming, Ohio.

[ABSTRACT.]

IN passing through Wyoming, Utah, Idaho and Nevada, during a recent trip to the Pacific coast, I fell in with various wandering tribes belonging to the Shoshone family of Indians, commonly known as Piutes. These are a migratory or nomadic family of hunters, made up of various Shoshone tribes, which wander about New Mexico, Nevada, Utah and Colorado, and number some 15,000. They are met with at almost every stopping place along the line of the Union Pacific and Southern Pacific railroads, over which they are allowed free passage, under certain restrictions, by express provision of the U. S. Government. At Winnemucca, Nev., I met a large

mixed delegation of both sexes on the way to a council-fire about to be held at or near South Mountain on the Owyhee river in southwestern Idaho. Among them was a Tookarika "medicine man," whose services were called into requisition during my short stay among them, in behalf of a sick papoose, in the last stage of cholera infantum. I was naturally curious to observe his treatment of the case, which consisted in giving to the child a strong decoction of *Arbutus mariania* leaves,—a plant abounding in tannin, on which, no doubt, its curative action depends. The Piutes not only use the leaves of this plant as a medicine, but they smoke them like tobacco, and also produce with them a black dye. Finding that this itinerant native doctor was in high repute among his fellow Piutes for his medical skill, I prevailed upon him, by the gift of a gaudily colored blanket, to share with me his collection of specifics, and to impart to me their local names and their medical properties. In this way I became possessed of the following list of medicinal plants in common use among the Piute Indians. I will add, that the information thus obtained was abundantly verified by other Piute Indians met with at different points along the route. I also observed that in several instances the local names given were apparently of French or Spanish origin, a circumstance easily accounted for by the migratory character of these tribes.

BRIEF LIST OF MEDICINAL PLANTS IN COMMON USE AMONG THE PIUTE INDIANS.

Scientific Name.	*Local Name.*	*Medical Properties.*
Juniperus occidentalis, Lin.	Henevro.[1]	Diuretic, Uterine.
Opuntia vulgaris, Mill.	Tunas.[2]	" "
Rhus aromatica, Ait.	Squawberry.[3]	Astringent.
Arbutus mariania, Raf.	Sagack.[4]	"
Caulophyllum thalictroides, Lin.	Squawroot.[3]	Emmenagogue.
Convolvulus panduratus, Lin.	Mechameck.[5]	Cathartic.
Aplectrum lutescens, Ait.	Mocasin.[5]	Nervine, Uterine.
Eupatorium urticefolium, Raf.	Deerfoot.[3]	Febrifuge.
Gillenia stipulacia, Lin.	Hippo.[6]	Cathartic.
Hedeoma pulegioides, Lin.	Squawmint.[3]	Carminative and Emmenagogue.

[1] Indian, but probably of Celtic origin. [2] Spanish. [3] English. [4] Indian, but of French origin. [5] Indian. [6] Of Spanish origin.

ADDENDA.

Juniperus occidentalis.—The fruit of this tree is a large berry, sweet and nutritious. It is largely consumed by the Piutes, being stored up in large quantities for winter use.

Opuntia vulgaris.—The fruit of this and other allied species of cactus is much eaten by the Piutes.

Rhus aromatica.— The fruit of this plant is dried and used as food by various Piute tribes.

"EYAH SHAH:" A SACRIFICIAL STONE OF THE DAKOTAS. By Rev. HORACE C. HOVEY, Minneapolis, Minn.

[ABSTRACT.]

IT was the custom of the Dakotas to worship bowlders when in perplexity and distress. Clearing a spot from grass and brush they would roll a bowlder on it, streak it with paint, deck it with feathers and flowers, and then pray to it for needed help or deliverance. Usually when such a stone had served its purpose, its sacredness was gone. But the peculiarity of the stone now described is that from generation to generation it was a shrine to which pilgrimages and offerings were made. Its Indian name, "Eyah Shah," simply means "the Red Rock," and is the same term by which they designate catlinite, or the red pipe clay. The rock itself is not naturally red, being merely a hard specimen of granite, symmetrical in shape, and about five feet long by three feet thick. The Indians also called it "Waukan" (mystery) and speculated as to its origin. It lies on a weathered ledge of limestone, and evidently has not been moved since it was left there by glacial action. The Indians looked no further than an adjacent hill down whose sides they claimed to trace its path to the river bank. The particular clan that claimed this rude altar was known as the Mendewakantons; although being but two miles below the village of the Kaposias, it was to some extent resorted to by them likewise. The hunting ground of the clan was up the St. Croix, and invariably before starting they would lay an offering on Eyah Shah. Twice a year the clan would meet more formally, when they would paint the stone with vermilion, or as some say with blood, then trim it with flowers and feathers, and dance around it before sunrise with chants and prayers. Their last visit was in 1862, prior to the terrible massacre that occurred — August of that year. Since that date the stripes were renewed three years ago. I counted the stripes and found them twelve in number; each about two inches wide, with intervening spaces from two to six inches wide. By the compass, Eyah Shah lies exactly north and south. It is twelve paces from the main bank of the Mississippi, at a point six miles below St. Paul. The north end is adorned by a rude representation of the sun with fifteen rays. I am not aware that this relic was ever described before it was done by myself.

OBSERVATIONS ON THE IROQUOIS LEAGUE. By Rev. JOHN W. SANBORN, Albion, N. Y.

[ABSTRACT.]

HISTORICAL facts concerning the League of the Iroquois are briefly stated in this paper, and authorities are quoted for the purpose of approximating as nearly as possible the real date of the origin of the League, which is believed to be about 1469.

THE ORIGIN AND ANTIQUITY OF THE N. Y. IROQUOIS. By Rev. W. M. BEAUCHAMP, Baldwinsville, N. Y.

[ABSTRACT.]

THE New York Iroquois were shut in and weak when the Dutch entered that State, but soon became powerful. No Algonquins had ever occupied their original territory, and no nation had lived in the Mohawk valley before 1550, there being but two prehistoric village sites there. Grooved stone axes and shell beads are accidental and rare on Iroquois and kindred prehistoric sites, showing they had not yet reached the ocean. The Five Nations came from different branches of the family, as shown by tradition, history, their language, customs and remains. The Mohawks were certainly from the St. Lawrence, and the Oneidas apparently from the same source; the Onondagas came from the east end of Lake Ontario; the Senecas from the Eries, and probably the Cayugas also. In their early home territory prehistoric sites are few except in Onondaga county. The Mohawks were in Canada in 1535, and may have come to New York in 1550, the League being formed later. The names and emblems of the nations are recent and can barely be connected with prehistoric times; in some cases hardly at all. The first historic notices give no intimation of a league, and the Onondaga legend of Hiawatha is a corruption of the life of Christ. Apparently a loose alliance might have been formed a little before A. D. 1600. [This paper is printed in full in the American Antiquarian, Nov., 1886.]

WAMPUM. By Rev. W. M. BEAUCHAMP, Baldwinsville, N. Y.

[ABSTRACT.]

TRUE wampum was not used inland in New York before A. D. 1620, and scarcely any shell beads or ornaments of any kind are found on the inland prehistoric sites of that State. The early Iroquois had no wampum, but obtained it from the Dutch, and seem to have been the first to use it in belts at treaties. The manufacture rapidly increased, though for the first century mostly in the hands of the shore Indians. Large quantities were made, and it was long the Dutch colonial currency. The first recorded emblematic belt was given by the Mohawks to Le Moyne in 1656, having a sun worked with 6,000 beads. A great many have been described since. The largest one mentioned was of 18,000 beads, but this was narrower than a defective belt yet at Onondaga. Fifty belts have been used at a single council, and 100 were prepared for the New York Indian ambassadors to the Scioto council. Sir William Johnson often employed 100,000 to 150,000 wampum at a conference. Color was not always significant, and strings of wampum and painted sticks sometimes took the place of belts. The belts were often painted, or worked with figures or letters, articles being sometimes attached. Classes of belts were accurately distinguished as peace, war, covenant, scalp, and many others. Strings are still used by the Iroquois in national and religious ceremonies.

SOME FACTS INDICATING A GREATER ANTIQUITY FOR THE ANCIENT CHIRICANOS THAN IS GENERALLY CONCEDED. By J. A. McNIEL, Binghamton, N. Y.

[ABSTRACT.]

1. THE fact that in Chiriqui, a department of the State of Panama, U. S. C., but few of the ancient graves are found at a lower altitude than about 500 feet, while human bones have not been found in those of 2000 feet altitude. 2. A singular break in a hill in lat. 8° 50′ N. and long. 82° 45′ W. (of G.), which evidently divided one of the ancient cemeteries many centuries ago. 3. Absence of all traces of structures above ground. 4. The gradual rising of the land which is still taking place.

THE DEPARTMENT OF CHIRIQUI: ITS POTTERIES, STONE AND METAL IMPLEMENTS. By Dr. WOLFRED NELSON, New York, N. Y.

[ABSTRACT.]

A PAPER on the Department of Chiriqui in the state of Panama. Being a brief description of its prehistoric *guacals* or graveyards, the contents of the *guacas* or graves, such as potteries, stone and metal implements and other objects, accompanied by four large photographs of a remarkably fine collection made by Mr. J. A. McNiel, for seven years a collector in Chiriqui.

TORSION OF THE HUMERUS IN NORTH AMERICAN INDIANS. By Dr. FRANK BAKER, Washington, D. C.

[ABSTRACT.]

MEASUREMENTS of the angle of torsion of humeri of North American Indians do not show that any law can be deduced therefrom with reference to a phylogenetic development of that torsion.

NOTES ON RECALCIFICATION OF HUMAN TEETH. By J. R. WALKER, D.D.S., Bay St. Louis, Miss.

[ABSTRACT.]

THE extent to which general human development depends upon the proper utilization of food is such that any fact bearing upon the success of this process is a very important one. About twenty years ago my attention was called to the fact that in the city of New Orleans there is a larger prevalence of soft, decalcified teeth than is usual in other localities.

By careful observations I became convinced that it was a question of environment and due chiefly to the character of the food elements, principally the water used.

Various circumstances combine to render the general food of the inhabitants of New Orleans, poorer in limesalts than in other sections of the country, the most important factor, however, being the almost exclusive use of cistern water for potable purposes; this contains no limesalts, being merely a solvent. These general conditions prevail over a large extent of country bordering on the Gulf of Mexico, but seem to be more apparent in effects in New Orleans than elsewhere.

Having satisfied my own mind as to the cause, I next sought the remedy and naturally looked in the direction of the phosphates, the chief element in the composition of the teeth.

A faithful administration of the phosphates, in every way in which they could be obtained failed to secure any satisfactory results; and I found the statement thoroughly true that "The system will not take the elements from any ready-made source; it must elaborate its own pabulum." Those who live in mountainous and other regions, well supplied with calcific elements do not get calcis in the form of the phosphate.

Acting upon this suggestion I found that the administration of the pure aqua calcis produced results as thoroughly satisfactory as the experiments with the phosphates had proved unsatisfactory, and that given in this form or in the form of syrup of lime it is possible not only to prevent the decalcification of teeth, but to recalcify those that have been softened by the removal of the lime salts, and in the raising of children to overcome both environment and heredity.

An Indian secret society. By Rev. J. Owen Dorsey, Bureau of Ethnology, Washington, D. C.

[This paper will form part of "Osage traditions" to be published in the Sixth Annual Report of the Bureau of Ethnology, Smithsonian Institution.]

Uses of the terms grandfather and grandmother among Siouan tribes. By Rev. J. Owen Dorsey, Bureau of Ethnology, Washington, D. C.

Gold and silver ornaments from Florida mounds. By George F. Kunz, New York, N. Y.

Gold ornaments from the United States of Colombia. By George F. Kunz, New York, N. Y.

A QUERY AS TO THE SEPULCHRAL RITES OF THE MOUND-BUILDERS. By EDWARD P. VINING, Chicago, Ill.

LIMITS REGARDING A KNOWLEDGE OF THE ORIGIN OF LANGUAGES. By JNO. MÜLLER, Ann Arbor, Michigan.

THE MAORI OF NEW ZEALAND COMPARED WITH OTHER MEMBERS OF THE POLYNESIAN GROUP. By JNO. MÜLLER, Ann Arbor, Mich.

CHILD MIND. By Rev. GEORGE M. MAXWELL, Wyoming, Ohio.

ANCIENT FORTIFICATIONS IN THE OHIO VALLEY. By Rev. GEO. M. MAXWELL, Wyoming, Ohio.

ANCIENT ART IN CHIRIQUI. By J. A. MCNIEL, Binghamton, N. Y.

LONGEVITY OF GREAT MEN. By JOSEPH JASTROW, Ph.D., Germantown, Philadelphia, Pa.

THE DIVERSITY OF THE MOUNDS AND EARTHWORKS IN THE UNITED STATES. By F. W. PUTNAM, Cambridge, Mass.

THE METHOD OF MAKING THE BONE FISH-HOOKS FOUND IN THE OHIO VALLEY. By F. W. PUTNAM, Cambridge, Mass.

SECTION I.

ECONOMIC SCIENCE AND STATISTICS.

ADDRESS

BY

JOSEPH CUMMINGS, LL.D.,

VICE PRESIDENT, SECTION I.

CAPITALISTS AND LABORERS.

THE adjustments of the relations of Capital and Labor, and the just division of the profits from their joint use, present problems that have baffled the skill of the wisest men. Serious difficulties have in ages past been connected with the subject, but at no time have they been so great as now. Many students of social science have felt as did Mr. Norman Senior, who at the age of twenty-five years determined to reform the condition of the poor of England, but after years of labor felt that there was a very strong contrast between the insignificance of the performance and the greatness of the project entertained. Alienation and bitterness of feeling between capitalists and laborers have increased with the advance of civilization and an increase of the comforts of social life. There are threatening indications and ominous signs of evil that should awaken serious alarm. There is great danger of the disturbance of social order and the overthrow of our civil institutions. There are in our country millions of discontented people with more or less hatred of our institutions, which, in their view, favor the rich and oppress the poor. There are thousands of well-armed, well-drilled men pledged to the work of destruction and the overthrow of government. The large number of papers having a wide circulation is an indication of their strength. These journals and the leaders of public meetings teach the most extreme, destructive, and terrible doctrines. They affirm that the present order of society must be overthrown; that it is vain, worse than useless, to rely on the ballot; that the people must abandon this and resort to violence, they must use dynamite and other explosives. In all trades-unions the

best men should be selected for the study of chemistry and devices for destruction. There is no form of crime and violence which may further their objects that is not indorsed. "Hypocrisy, fraud, deceit, adultery, robbery, and murder are held sacred when beneficial to revolution." "Assassination of members of the ruling classes of capitalists is held justifiable and commendable." "Plundered as we are by the proprietor who limits our air and light, we must come forth from the cellars and attics in which our families struggle for existence, and establish ourselves in those splendid buildings, which have been raised at the cost of so much toil and suffering, and in those spacious apartments in which there is an abundance of pure air, and where the sunlight will throw its life-giving radiance upon our little ones. We must take possession of the great warehouses and stores in which the rich man now finds the means of gratifying his caprices, and lay our hands, for the common good, on the enormous quantity of products of all kinds necessary for our nourishment and for our protection from the weather."[1]

One of their influential journals says: "In the depths of his nature the revolutionist, not only in words, but also in deeds, has fully broken with the civil order,—with the laws currently recognized in this world, with customs, morals, and usages; he is the irreconcilable enemy of this world, and if he continues to live in it, it only happens in order to destroy it with the greater certainty. He knows only one science, namely, destruction. For this purpose, and for this alone, he studies mechanics, physics, chemistry, and possibly medicine. For this purpose he studies day and night living science, men, characters, relations, as well as all conditions of the present social order, in all its ramifications. He despises and hates the present social morality in all its teachings and in all its manifestations. For him everything is moral which favors the triumph of the revolution, everything immoral and criminal which hinders it."[2]

All this may seem like the rantings of a crazy fanatic, but there is a terrible earnestness with the teachers who utter such sentiments which may be translated into action that shall cause widespread destruction of property and life. While the enemies of

[1] Recent American Socialism, by Richard T. Ely, p. 36.
[2] Ibid., p. 39.

order may not be able to overturn our institutions, they may cause incalculable evil. We have seen illustrations of the destruction and dismay that a few desperate, bold outlaws may cause. In the riots of 1877 it is estimated that property worth a hundred millions of dollars was destroyed, and very many persons perished. We are in constant peril that similar scenes may occur. A citizen soldiery is not successful in suppressing riots in the community in which they live. Even when criminals are arrested, it is extremely difficult to secure just punishment. Through fear of personal violence, or for selfish regard to their business or other interests, good citizens nearly, if not quite, perjure themselves to escape service as jurymen, and through technicalities of the law or through corruption criminals escape. Modern discoveries and inventions have placed fearful instrumentalities of destruction within the reach of any who are wicked enough to use them. Such means may be used also with little danger of detection and punishment. In these circumstances, there is reason for alarm, and it is worse than folly to shut our eyes to the danger, and talk of the stability of order and social institutions.

IMPROVEMENT IN THE CONDITION OF LABORERS.

In the discussion of the difficulties between capitalists and laborers, we should not forget that the great improvements and inventions that affect society, multiply sources of comfort, prolong life, and add to its enjoyments, have greatly improved the condition of laborers, as well as that of other classes. The improvement is too evident to need discussion and proof. All readers of Macaulay will remember his splendid description of the improvements science and civilization have conferred on those engaged in common toil, and the great contrast in the condition of society as compared with that of two centuries ago. The poorest man has now comforts and the fruits of varied climes that those in the highest condition of wealth or rank could not command; and when he meets with serious accident and needs surgical aid, or is affected with painful disease, he has the benefit of surgical and medical skill that formerly not greatest wealth nor royalty itself could secure.

In his work on "The Progress of the Working Classes in the last Half-century," Mr. Giffen has shown, in carefully prepared tables, in which the wages paid in common representative employ-

ments are given, that there is an advance in some cases of twenty per cent, in most cases of fifty to one hundred per cent, above what was paid fifty years ago.

In England there has been a great rise in wages paid agricultural laborers, which are stated by Sir James Caird to be sixty per cent higher than at the period just before the repeal of the Corn Laws. While the wages have increased from fifty to one hundred per cent, the workman on account of the lessening of the hours of labor does twenty per cent less work; therefore he gains from seventy to one hundred per cent in money returns.[1] It is an important fact that, when the relative value of money to commodities is considered, the same amount of money will purchase as much food and comfort as fifty years ago. There are many new and desirable articles in existence at a low price, which could not formerly be obtained at any price. As the means of communication and the facilities of commerce have increased, there is much less fluctuation in prices than fifty years ago. "Then the sudden contrasts in prices were most disastrous, and often caused great distress. Periodic starvation was in fact then the condition of the masses of workingmen throughout the kingdom."[2] Food is cheaper now; the only article to be excepted is meat, which was not then an article of the laborer's diet. House rent is indeed higher, but the poor have far better accommodations; less taxes are paid and more received than formerly. Fifty years ago in England the masses had little education, and that was comparatively poor; no provision was made for general education. In 1851, in England, the children aided by the government in average attendance at schools numbered 239,000, in Scotland 32,000; in 1881 the figures were 2,363,000 and 410,000.[3] The statements of Mr. Giffen relate to Great Britain. It is difficult to determine with the same exactness whether a corresponding change has taken place in the United States; but, from statements that are worthy of confidence, it appears that for the past fifty years there has been a "continuous reduction in the hours of labor, coupled with an increase in the earnings per hour, and an increase in the purchasing power of gold in respect to almost all articles of necessary subsistence." I have no sympathy with the use often made of this fact of the improvement in the condition of the laboring classes, when it is

[1]Giffen, p. 9. [2]Giffen, p. 12. [3]Giffen, p. 21.

urged that they should be thankful, and cease from their complaints and efforts for change, which endanger the established order of society. Why should the exhortation to be contented have more force with them than with others? Is there not too prevalent an opinion that there must be fixed classes in society, and that a position in the most favored class must not depend on personal worth or intellectual ability? There is an assumption in what is called good society, and among respectable people, as they are termed, that the majority must work hard enough to relieve a privileged minority from labor. If this laboring class have food and provision for shelter and repose, together with fitting changes of raiment, "why should they not be content?" [1]

If laborers were only a higher kind of oxen and horses, made to toil for the benefit of a higher race, this kind of argument might have force. Even for intelligent, faithful brutes, food and shelter are not enough. They have a right to expect kindness, appreciation of their qualities, and a certain kind of respect. Man is not a mere animal, and mere toil is not the object of his being. It is a condition from which it is right to seek exemption. All men have the same powers, the same tastes. Susceptibility of culture depends not on outward conditions. The highest talent is not that which secures gain directly or indirectly. Many of the most gifted are crushed by burdens not natural, which they cannot throw off. Contentment and happiness depend on our knowledge, on the cultivation of the faculties. A savage with the range of the forest, his wigwam, his bow and arrow, and plenty of game, is happy in an animal existence. Transferred to civilized society, his desires for higher good awakened, his tastes improved, he becomes miserable for want of an unattainable good, before neither known nor sought. So is it with the laborers of to-day. Their field of vision is extended, their desires for good are awakened, knowledge is increased, taste cultivated, and in comparative prosperity they are more miserable than in their former degraded condition; they understand more of the relations of diverse classes, and justly claim they have not their share of the good that has resulted from their toil. Separation, class distinctions between the capitalists and laborers, are greater than at any preceding time. Formerly the employer and the laborer had close personal relations. They

[1] William T. Thornton on Labor, p. 19.

worked together in the shop or field, they sat at the same table, and had common social privileges. Now they are strangers, and have little in common. The introduction of steam has led to their separation. There are large manufacturing establishments that have crushed out smaller ones, and laborers are gathered in large numbers, and, instead of making, as formerly, the whole of various articles, their labor is confined to some small part. They are comparatively helpless when they are out of employment; hence they are dependent on employers, and in self-defence resort to combinations, and often to violence, to retain their places and secure support for their families.

With all our boasted advantages of modern civilization, the condition of a large portion of the laboring class is pitiable, and calls for earnest thought. Thousands have no employment, and thousands more are compelled to live on a mere pittance, and submit to conditions that are destructive of all manhood and nobility of spirit. Cheap labor is a community curse, a barbarism, and implies a degraded condition of society. In the last Report of the New York Bureau of Labor Statistics, it is stated that 200,000 women and girls are employed in New York City in about 92 trades. In cigar-making 6,000 are employed, 4,000 working in tenement-house shops; they earn about $8 per week. One cigar factory employs 12,000 girls at $4 per week. There are 4,000 laundresses in the city, and the highest wages paid are $6 per week. Hundreds of cases are reported where women work from fourteen to seventeen hours per day, at from $4.50 to $7 per week. Loss of time from inability to obtain work reduces their annual earnings till they barely sustain existence. Many of the employments are detrimental to health. Sewing girls and workers in the dry goods line receive in some cases only 12½ cents a day. Many of them are wronged, and on various pretexts deprived of their pay. The Women's Protective Union have on their records 40,689 who were assisted to receive their wages. The rules in many factories are abusive and degrading. There is an outrageous system of imposing fines, which in many cases equal the wages promised. The home life of these women, and others with whom they associate, could hardly be worse. It is said that 18,996 tenement houses accommodate fifty persons each, and not a few three times as many. It is in such conditions young girls are brought up, in which decency and womanly reserve are impossible. The sani-

tary conditions of life in such tenements are horrible beyond description.

This statement will apply to many other places, and indicates the many thousands of people whose life is one extended scene of misery and hopeless struggle with want. Such a condition of so large a number of the poor is a reproach to any age. It cannot wisely be expected that desperate men will lie down contented in their noisome cellars, or in crowded stories above stories, where want, misery and crime are herded together, and abstain from violence, pillage and anarchy. Such is the present state of society and the unequal division of wealth, that, while the state of the laborers may be far better than it was a century ago, yet as a class they do not receive a fair share of the gain from labor and capital. It is a sore evil that has resulted from the effectiveness of machinery, that it separates the wage-workers into a permanent class, making it more hopeless for them to rise above it. The minute divisions of labor, and the uncertainty of steady employment resulting from excessive competition and over production, still further degrade labor.

CAUSES OF THE DISCONTENT OF LABORERS.

There are serious causes of the widespread discontent. They underlie all differences as to present and future contracts and the ever-recurring question, "What is a fair day's wages for a fair day's work?" — a question that can receive no final answer, since what may be fair one day may be unjust the next.

One great cause of the discontent and difference between capitalists and laborers arises from different views as to the relation of the employers and employed. Within fifty years these relations have greatly changed, a fact very many ignore. Once it was the privilege of the employer to command, the duty of the laborer to obey. The diffusion of the doctrine of human equality has led the masses to such practical application as a denial that respect is due to men because of outward circumstances. The education of the masses has led them to demand more attention and respect. Those who believe in distinctions founded on birth and circumstances, and not on personal power and worth, have always denounced the idea of educating the masses. It is said that it would be an evil to them, and make them discontented with their state. Their lot, it is said, is, and must be, to labor for the few; why,

then, should other ideas be taught them? No education was permitted to slaves, and he who should attempt to teach them any principle but submission was regarded as the foe of society and severely punished.

Education and the actual recognition in a practical form of the equality of men, and the doctrine that governments derive their just powers from the consent of the governed, that the people are the source of power, have changed the relations of classes in society. Maxims like the general principles of equality and liberty may be proclaimed as glittering generalities, and not really be understood by those to whom they are addressed. Thus the slaves attended the celebration of the independence of the nation, heard the Declaration of Independence read, and never had a thought that the truths to which they listened had any application to them. But the people now understand these truths, and the tendency is to carry them to excess. The danger from the perversion of these principles is increased by the coming to this country of hosts of the ignorant and degraded, who have lived in a condition but little above serfdom. They learn the words liberty and equality from laborers of a higher class, but, not understanding their meaning, consider that they are free from restraint and law, and engage in acts of riot and anarchy that tend to overthrow government and overturn society.

In former times labor was despised. "Citizenship," says Aristotle, "belongs only to those who are not obliged to work for a living." The mass of laborers were slaves. Socrates, as cited by Professor Schmidt, says: "It is right to despise those who have not leisure from work to devote themselves to their friends and the public." Who are the people? Is it that cordwainer, that public carrier, that tent-maker? You despise each one individually, why not despise them all in the mass? Aristotle says: "We cannot dispense with farmers and mechanics, but these have nothing to do with public offices and are not worthy of the name of citizens. They are incapable of greatness of soul, and cannot have any manliness because they work for wages and therefore must be of a mercenary spirit."[1] The same ideas existed in a less exaggerated form in feudal days. They are still enforced by much of the legislation, teachings, and usages of modern times. The employer con-

[1] New Englander, Vol. XXIX, pp. 251, 252.

siders himself superior to the employed. He assumes the right to decide all questions that arise in connection with wages, in the decision of which the laborer has an equal interest with himself. He will not be dictated to relative to the use of his property. If discussions take place, they are permitted. "An interview is granted." The employer assumes the right to dictate the mode of the interview. "No committee will be recognized," etc.[1]

Everywhere there is an assumed superiority of condition which does not exist.

The principles of our government hold that justice is founded on right, not on might. Labor is service indeed for an equivalent. The employer and employed stand as equals in an interchange of service.

Even in American society there is still an exception to general principles. All labor which involves personal attention, and especially labor in household service, is still degrading. The term servant is still used, but it should be banished from a civilized people, and become as obsolete as slave and serf.

There is a prevalent error as to wages. It is not true they are paid by the employer. The product of the joint effort of the employer and employed goes into the keeping of the employer, and he pays to the laborer what is his right, his just proportion.[2]

The employer has no more right to dictate to the laborer how he shall seek his interests, and what associations he shall form and what trades-unions he shall establish, than the laborer has to dictate to the capitalist in corresponding matters. A great part of the alienation between classes and the bitterness of the poor towards the capitalists lies in the fact that wages have been substituted for all other ties, and the laborers are regarded but as a part of "the plant" in a great manufacturing establishment.

The evil is serious and increasing. So numerous and efficient have become labor-saving inventions, and so marked are the improvements in the new modes of business, that there is an increasing surplus of labor. The great question is, "What shall be done for the multitude, wanting and willing, as well as needing and seeking employment?" The evil in our country has been increased by the rush of millions from less favored countries to seek subsistence here. We do not think, when we read of the hordes of Goths,

[1] Joseph D. Weeks, Labor Differences and their Settlement, p. 10.
[2] Ibid, p. 11.

Vandals and Huns, that in olden times rolled in upon Southern Europe and destroyed its civilization, that in numbers they were small in comparison with the masses that have flowed in upon our country.

It is a bitter, cruel mockery to tell the masses, in their hopeless degradation, of the few who have risen from the lowest condition to the highest state of prosperity, wealth, and power. They are evidently exceptional cases. What society wants to know is, not how those who have the greatest natural gifts succeed, but how those who from nature are in these respects below mediocrity shall gain comfort for themselves and families. Heretofore, in no other country could a talented laborer rise so rapidly to be a capitalist as here; but the difficulty of doing this has increased, and is still increasing. Machinery is so costly that its ownership requires large capital. Competition has so reduced profits that a large business is essential to the realization of considerable gain. A large business requires large capital. The cases of success without capital are becoming few. "The man at the bottom of the ladder leading to the social heavens may dream that there is a ladder let down to him; but the angels are not seen very often ascending and descending. One after another, it would seem, some unseen hostile powers are breaking out the middle rungs of the ladder; and it becomes harder and harder even for the strong who are down to climb up."

ERRORS OF THE LABORERS.

Most of the writings of socialists present no clear statement of the difficulties or the principles involved in their controversies with capitalists, and their teachings are merely negative. They urge the destruction of the present order of society, but give only vague, dreamy ideas, of a better state, with no principles or theories by which to reconstruct society, and reach that ideal state where all will have abundance, and freedom from painful care and the necessity of toil. There are, however, principles widely diffused, that have a powerful influence on the masses. They are artfully urged, and seem true, but they are great fallacies. Mr. Scudder states them thus.[1]

1. All wealth is created by labor.

2. The title to all wealth ought to be vested in the laborers who have produced it.

[1] M. L. Scudder, Jr., Labor Value Fallacy, p. 10.

These propositions have been more or less directly taught by leading writers, and to many minds they appear to be self-evident truths. Carried into practical application, they would overthrow society and reduce nations now wealthy and civilized to barbarism.

It is a narrow view, that mere toil, manual labor, has secured the wealth of civilized society. Little would this labor avail without right direction, without the thought and genius that devised inventions and modes for the accumulation of capital, essential to complete the great and costly enterprises on which the welfare of society depends. The contest between labor and capital is a contest, indeed, between present labor and accumulated labor. Their true interests are identical. Capital is necessary for the construction of machines, the building of railways, of ships, and the completion of all great enterprises. Should the laborers who construct a railway or erect a factory advance the absurd claim that they are the owners and managers, what good or profit could result? Only loss and destruction would follow. It is an unfounded assertion, that all value is created by manual labor. A slight observation shows that often where much labor has been bestowed there is no value. Prices or values in the market are not determined by any one consideration or class of considerations.

The works of Mr. Henry George have had a wider circulation than any other works recently published. His doctrines have been received with favor by many who would not accept and act on his conclusions. Their fallacy has been clearly expressed, yet still they have power with the popular mind. He writes in a popular, spirited, and persuasive style, and makes pleasing promises as to the good that would follow the adoption of his principles. He teaches that the wealth of the few should be divided among the many, and advocates in a way to attract attention an idea which stronger men have urged, that the state should assume possession of all land, and, as the landlord, rent it to individuals, and appropriate the increase from rent to the relief and comfort of the poor. He claims that nature gives wealth to labor and only to this: every article of wealth has been gained by labor which has searched for it or made it out of raw materials. He says: "Hence, as nature gives only to labor, the creation of labor in production is the only title to exclusive possession." He flatters the masses by telling them all power is with them; they should not ask for patronage or charity, but demand their rights. Such teachings have a most perni-

cious influence. They lead the poor, who believe that inequality of condition is a wrong, to exercise their power to produce a uniformity of condition, which they are told characterizes a perfect society. They neglect their employments, are discontented, strive for what is unattainable, lessen their gains by inattention to their employments, and needlessly increase their want and misery.

All the teachings of nature and Scripture show that men must be unequal in natural faculties, and unequal in condition. This law applies to the highest as well as the lowest powers. The notion that there can be a state in which all shall be equal in power, mental or physical, and in the results of the exercise of power, is a dream of the wildest fanaticism.

REMEDY FOR THE DISCONTENT AND DIFFERENCE.

It is evident there are grievous differences between the capitalist and the laborer, and reasons for serious alarm. The remedies proposed are various, but we shall not discuss them at length, as manifestly they are failures. Such is the case with what is called the *laissez faire* method, which implies unrestricted competition. The capitalist offers such wages as his interests in his view require, and seeks his laborers where they may be found, and the laborers act in a corresponding manner. The advantage is evidently with the employers. The laborer is degraded, as labor is regarded as a commodity to be bought and sold in the markets. The facility of change of residence on the part of the laborer is greatly restricted. Moreover, the bitter opposition to foreign labor, the rules of industrial societies, and well-established customs and conditions, fatally interfere with this theory so far as the interests of the laborer are concerned. Personal violence, disgrace, and lasting injury result to those who disregard these rules and customs.

Competition places the two chief classes of industrial society in opposition, and encourages strife. It encourages combinations, and leads to strikes and lockouts. The motive itself is unworthy, degrading, selfish, and inconsistent with the principles of true benevolence and civilization. We deem it not necessary to discuss strikes and lockouts, which are not a remedy, but an evil, a source of bitterness to both parties, and only resorted to as extreme measures to obtain justice when other methods fail. While those engaged in strikes generally lose heavily, yet they may be a benefit to workmen; as employers, dreading their recurrence, may make concessions to demands that would not without this fear be granted.

CONFERENCE AND ARBITRATION.

A reasonable mode for the settlement of difficulties would be a conference between the classes interested, or their representatives. The opinions of the opposing parties may be honest, yet by mutual explanations and concessions a settlement may be reached, and harmony and mutual good feeling and respect secured. The greatest difficulty in the way of such a mode of settlement is the unjust and foolish course of many employers who will not condescend to confer with laborers, claiming that the decision of all questions connected with business belongs to them, and any interference with their assumed rights is an impertinence. Such views are not to be tolerated to-day. They belong to former times. The capitalist and the laborer are partners in production, and both have an equal right to a participation in the decision of questions in which their interests are involved. This right the laborer will now, with emphasis, demand, and it is wrong, vain, and dangerous to oppose his claim. Such conferences would have a great influence in removing the obstinacy and false pride that are fruitful causes of difficulty and would bring about that respect and courtesy essential to all successful negotiations between capitalists and laborers. When a settlement cannot be reached by a conference, it would seem the wisest course to refer the points in dispute to arbitrators, chosen in the usual way. Great responsibility would of course rest on the umpire chosen by the other arbitrators. But it is not difficult to find a man of sufficient intelligence and firmness to give a just decision. It is not necessary that he should have technical knowledge of the business or trade. He will be as well prepared to give a decision as are judges of courts before whom questions of the greatest variety are daily brought. The loss that would result to either party from arbitration would be less than would otherwise be incurred, and there is no humiliation or loss of self-respect in submitting to the decision thus given. In the Chicago Rolling Mills there is a mode of settlement of differences between the proprietors and the laborers that has given mutual satisfaction and secured the best results. The chief points of this method are: (1) Wages are based on a sliding scale in proportion to prices received for the product. (2) The organization of the men, so that they may readily appoint representatives to confer with the employers on points when there is misunderstanding. (3) Peaceful arbitration of all the difficulties which cannot be settled by a con-

ference between the parties interested. (4) Work is to continue without interruption pending the decision.

This provision for the settlement of difficulties would seem to be a wise one, and worthy of general adoption.

Boards of arbitration may be either temporary or permanent. There are many reasons in favor of permanent boards. It is far more important to provide means to prevent difficulties than for their settlement. Being already in existence, and meeting often, they would consider troubles before they should become serious. One of their greatest benefits would be their tendency to remove the antagonism of the two classes. They would meet as equals, and discuss difficulties before they give rise to disputes. Each class would have an understanding of the difficulties of the other. The workman would gain important knowledge of the condition of trade and prices, and other facts not otherwise easily acquired. The longer such boards should exist, the greater would be the fund of facts, precedents and useful knowledge. In foreign countries such boards have been established by law. In our country several states have enacted laws relative to them, and Congress has given the subject much attention.

We are persuaded that the present difficulties that threaten the peace and order of society will never be removed till a higher standard of ethics shall prevail. They are the direct result of selfishness, encouraged by the prevalent selfish theory of morals. There are personal sins and social wrongs that civil government may not by law or force correct. It is not according to the will of God, as made known by natural or revealed religion, that a few should control vast fortunes, using them to gratify selfish personal desires, while multitudes suffer, not only for want of knowledge but of bread, and struggle through a brief existence, realizing in no proper sense the true object of life. Nothing is right that is not in accordance with the Divine will; hence no man can have a right, though he has power, to do wrong. Because a gifted man has power to accumulate property, he has no right arrogantly to say, "This is mine, and I will spend it as I please." The wealth of the earth is designed for the public welfare, and it is their duty who have it in charge to consider themselves as agents, bound to use it so as to secure the greatest good. He who has wealth and does not intend to act thus is false to his trust, and is the enemy of society.

In the Christian use of money will be found the great remedy for

social wrongs. The right use of money will require much tact, wisdom and skill. Multitudes on multitudes of the poor have low, selfish, sensual aims, and indiscriminate giving to them would only encourage indolence and vice. They need education and culture, and higher ideas of life. All these, the right use of money, now worse than wasted, would secure.

The advance of society to a wider civilization is encouraging. Every age has had its difficulties; the greatest problem of ours is to settle the true relations of capital and labor. Whatever of doubt, difficulty, darkness and danger may now encircle us, the promise of the future is bright, and in due time will be realized — what good men in visions have seen — a society in which all shall have comforts, intelligence and virtue.

PAPERS READ.

Tables showing for a series of years the rates of interest realized to investors in the securities of the United States Government. By E. B. Elliott, Washington, D. C.

TABLE I.

SHOWING the average prices, flat and net, distinguishing currency and gold, of the United States six per cent coin interest securities of 1881, and rates of interest realized to investors in such securities for the months of January and July of each year from January, 1862, to January, 1880, both inclusive.

Periods.		Six per cent coin interest securities of 1881.			
		Prices including accrued interest. (Flat.)		Prices *not* including accrued interest. (Net.)	Rates of interest realized to investors.
		Currency.	*Gold.*	*Gold.*	*Per cent.*
1862.	January.	89.625	87.439	87.189	7.236
"	July.	99.75	86.364	86.114	7.371
1863.	January.	99.875	68.487	68.237	9.737
"	July.	105.50	80.781	80.531	8.070
1864.	January.	105.50	67.846	67.596	9.945
"	July.	104.4375	40.464	40.214	16.668
1865.	January.	110.9375	51.312	51.062	13.455
"	July.	107.625	75.739	75.489	8.904
1866.	January.	104.1875	74.367	74.117	9.160
"	July.	108.4375	71.528	71.278	9.666
1867.	January.	107.4375	79.820	79.570	8.473
"	July.	109.875	78.820	78.570	8.674
1868.	January.	110.1875	79.558	79.308	8.624
"	July.	114.1875	80.019	79.769	8.618
1869.	January.	111.625	82.319	82.069	8.338
"	July.	120.34375	88.423	88.173	7.514
1870.	January.	117.03125	96.481	96.231	6.470
"	July.	114.125	97.710	97.460	6.324

Periods.	Six per cent coin interest securities of 1881.			
	Prices including accrued interest. (Flat.)		Prices *not* including accrued interest. (Net.)	Rates of interest realized to investors.
	Currency.	*Gold.*	*Gold.*	*Per cent.*
1871. January.	111.75	100.949	100.699	5.910
" July.	115.53125	102.786	102.536	5.665
1872. January.	115.1875	105.580	105.330	5.279
" July.	117.59375	102.882	102.632	5.624
1873. January.	116.84375	103.677	103.427	5.490
" July.	119.625	103.393	103.143	5.509
1874. January.	117.875	105.812	105.562	5.099
" July.	117.90625	107.188	106.938	4.821
1875. January.	119.00	105.778	105.528	4.988
" July.	121.59375	105.918	105.668	4.899
1876. January.	121.78125	107.962	107.712	4.406
" July.	120.40625	107.602	107.352	4.349
1877. January.	113.96875	107.214	106.964	4.287
" July.	112.09375	106.351	106.101	4.324
1878. January.	106.78125	104.585	104.335	4.645
" July.	107.4375	106.903	106.653	3.639
1879. January.	106.46875	106.469	106.219	3.384
" July.	104.6875	104.688	104.438	3.680
1880. January.	104.53125	104.531	104.281	3.059

Note.— This table may be read thus: For the month of January, 1862, the average currency price of $100 of the six per cent. coin interest securities of the United States maturing July 1, 1881, including accrued interest (or flat) was $89.625; the corresponding gold price was $87.439. The corresponding gold price, *not* including accrued interest (or net) was $87.189; and the calculated annual rate of interest realized to investors in these securities was 7.236 per cent.

TABLE II.

Showing the calculated annual rates of interest realized to investors in the United States six per cent securities maturing in 1881; in the four and a half per cent securities maturing in 1891; and in the four per cent securities maturing in 1907; during the months of January and July of each year from January, 1862, to January, 1880, for the sixes, and from January, 1877, and January, 1878, for the four and a half's and fours respectively to and including the month of July, 1886.

PERIODS.	RATES OF INTEREST REALIZED TO INVESTORS IN THE		
	6's of 1881.	4½'s of 1891.	4's of 1907.
	Per cent.	*Per cent.*	*Per cent.*
1862. January.	7.236	——	——
" July.	7.371	——	——
1863. January.	9.737	——	——
" July.	8.070	——	——
1864. January.	9.945	——	——
" July.	16 668	——	——
1865. January.	13.455	——	——
" July.	8.904	——	——
1866. January.	9.160	——	——
" July.	9.666	——	——
1867. January.	8.473	——	——
" July.	8.674	——	——
1868. January.	8.624	——	——
" July.	8.618	——	——
1869. January.	8.338	——	——
" July.	7.514	——	——
1870. January.	6.470	——	——
" July.	6.324	——	——
1871. January.	5.910	——	——
" July.	5.665	——	——
1872. January.	5.279	——	——
" July.	5.624	——	——
1873. January.	5.490	——	——
" July.	5.509	——	——

Periods.	Rates of interest realized to investors in the		
	6's of 1881.	4½'s of 1891.	4's of 1907.
	Per cent.	*Per cent.*	*Per cent.*
1874. January.	5.099	——	——
" July.	4.821	——	——
1875. January.	4.993	——	——
" July.	4.899	——	——
1876. January.	4.406	——	——
" July.	4.349	——	——
1877. January.	4.287	4.425	——
" July.	4.324	4.330	——
1878. January.	4.645	4.218	4.027
" July.	3.639	4.162	4.023
1879. January.	3.384	4.011	4.029
" July.	3.680	3.912	3 891
1880. January.	3.059	3.822	3.786
" July.	——	3.527	3.502
1881. January.	——	3.198	3.274
" July.	——	2.885	3.074
1882. January.	——	2.828	2.998
" July.	——	2.895	2.900
1883. January.	——	2.911	2.916
" July.	——	2.974	2.939
1884. January.	——	2.497	2.670
" July.	——	2.672	2.838
1885. January.	——	2.505	2.726
" July.	——	2.365	2.668
1886. January.	——	2.208	2.607
" July.	——	2.149	2.420

FORMULAS FOR DETERMINING THE UNITED STATES GOLD VALUE OF SILVER BULLION, WHEN THE LONDON PRICE PER OUNCE OF STANDARD SILVER AND THE PRICE OF STERLING EXCHANGE BETWEEN NEW YORK AND LONDON ARE KNOWN. By E. B. ELLIOTT, Washington, D. C.

[ABSTRACT.]

THERE has been of late a great fall in the value of silver relatively to gold, the world over, and it is desirable by some simple process, to find, at any time, the gold dollar value of silver bullion in New York, corresponding to changes in the market price of silver bullion in London, the latter place at present being the controlling market for the purchase and sale of silver.

The object of this paper is to present formulas for the ready determination of such values.

The number of grains of fine silver, multiplied by the price, at any given time in London, per ounce standard $\frac{111}{120}$ fine, and divided by 21,896.354 gives the gold-dollar value of the specified number of grains of fine silver, assuming sterling exchange to be at par.

It follows, as may readily be shown, that the London price of silver per ounce standard, at a given date, divided by 58.980 is the corresponding United States gold value of bullion in the legal tender silver dollar; and the same price of silver per ounce standard, divided by 63.060, gives the United States gold value of the silver bullion in a nominal dollar's worth of subsidiary coin (halves, quarters and dimes); and the same price per ounce London standard, divided by 57.927 gives the United States gold value of the silver bullion in the trade dollar (a merchandise or bullion dollar) of full weight; and the same price per ounce of silver, London standard, divided by 47.617 gives the United States gold value of the silver bullion in one ounce Troy of fine silver.

The lowest London price to which silver has ever fallen, was on the 6th of August current, when the price in London was 42 pence per ounce standard, or $\frac{111}{120}$ fine.

The corresponding gold price at the same date of the legal tender silver dollar, considered as bullion, was therefore, $71\frac{21}{100}$ cents; the corresponding gold price of the United States subsidiary silver coin of full weight, considered as bullion, was $66\frac{60}{100}$ cents; and the corresponding gold price of the trade dollar of full weight, considered as bullion, was $72\frac{505}{1000}$ cents; and the corresponding value of one Troy ounce of fine silver, considered as bullion, was $92\frac{67}{100}$ cents.

At this price, 42 pence per standard ounce $\frac{111}{120}$ fine, the relative value of gold to silver was $22\frac{45}{100}$ to 1, that is, one ounce of gold was worth $22\frac{45}{100}$ (nearly $22\frac{1}{2}$) ounces of silver.

Another illustrative fact may be given, of special interest, it may be, to citizens of Buffalo. On the twenty-fourth of July we learn by telegram, that on the twenty-third, the city comptroller of Buffalo "opened bids for the purchase of 5,159 silver trade dollars in the city treasury. The whole amount was awarded to James B. Colgate & Co., of Wall street, New York, at their bid of 75 $\frac{4}{100}$ cents each."

The price paid, according to the above statement appears to have been for each trade dollar 75 $\frac{4}{100}$ cents. The bullion value of the trade dollar, (a merchandise or bullion dollar) of 378 grains of fine silver, according to the London quotations of that day (twenty-third), was 43$\frac{13}{16}$ pence per ounce of standard silver($\frac{111}{120}$ fine); and assuming sterling exchange to have been at par, that is, \$4.86656 United States gold for each pound sterling, was 75 $\frac{634}{1000}$ cents; but, taking the sterling exchange to have been \$4.8675, as actually quoted on that day, the bullion value of such trade dollar was 75 $\frac{649}{1000}$ cents.

From the foregoing, it appears that the price paid for each of the 5,159 trade dollars purchased, to wit: 75 $\frac{4}{100}$ cents, was less than the market bullion value on that day of a full weight trade dollar by from $\frac{59}{100}$ to $\frac{61}{100}$ of a cent.

This difference, perhaps, may be attributable to the fact, that the trade dollars purchased were, of course, somewhat worn.

CENTENARIANISM IN THE UNITED STATES. By JOSEPH JASTROW, Ph.D., Philadelphia, Pa.

[ABSTRACT.]

THE returns of the number of centenarians as given in the United States census for 1880 are admittedly erroneous. The error is largest in the case of the colored people, where it attains to enormous dimensions; it is also considerable in the foreign-born population. The large number of centenarians returned by these classes is a sign not of exceptional longevity (for this would not affect the results to such an extent) but of the fact that the causes tending to the exaggeration of the number of centenarians are most active among them. *The nearer we approach to a state in which these causes are absent, the nearer to the actual truth do we arrive.* On this principle the average ratio of the number of centenarians to the population among the *native whites* may be applied to the whole country, thus reducing the number of centenarians from 4016, the number returned by the census to 806. (Attention is also called to the fact that the ratio of centenarianism has been gradually decreasing from 1830 on; but that this decrease is slightest from 1860 to 1870 on account of the freeing of the slaves, and it has been demonstrated that free negroes exaggerate their ages much more than slaves).

A further reduction is made by excluding the native white females for reasons afterward justified. The native-male-white ratio of centenarianism is then divided into that of the several states and territories, and a few of the worst of these rejected. The next step is to show a close connection between the prevalence of the exaggeration of the number of alleged centenarians with the prevalence of *illiteracy* and what is termed the *decimal exaggeration, i. e.*, the excess of the number at a "round" age such as twenty, thirty, etc., over the number at the age immediately preceding:— an excess which the doctrine of "expectation of life" shows to be impossible.

This connection being demonstrated those states only are retained in which both these factors—illiteracy and decimal exaggeration— are least active, and their average of centenarianism is applied to the total population

thus reducing the number of centenarians to about 150. Up to this point the native-male-whites have been regarded as perfectly reliable; this is evidently not the case and the estimate is hazarded, that inasmuch, as only one in twenty-five of alleged cases of centenarianism in the United States at large has proved genuine, one in *three* of those amongst the native-male-whites of the selected states may be considered as genuine, thus leaving about fifty centenarians in the United States, *i. e.*, one in a million. The original number 4016 is thus reduced to $\frac{1}{80}$, which agrees with the ratio that Mr. Thoms found in the cases of centenarianism which he investigated in England. It is hoped that such research will illustrate the great tendency for exaggerating high ages as well as shed light on the extremes of the life-periods in the human race.

ERRORS IN THE RICARDIAN THEORY OF RENT. By EDWARD T. PETERS, Washington, D. C.

[ABSTRACT.]

RENT defined and distinction between the economic and colloquial uses of the word pointed out.

The Ricardian theory of rent illustrated and stated.

Contention of Prof. Thorold Rogers (Manual of Political Economy, p. 155 *et seq.*, edition of 1879) that inferior land is not cultivated because of the pressure of increased population, but that increased population becomes possible and actually comes into being as the result of improved agricultural methods, under which inferior land becomes worth cultivation, and furnishes the increase of produce which is a *prerequisite* to increase of population.

Historically considered, the case has probably much oftener been as stated by Professor Rogers than as presented in the Ricardian doctrine of rent.

The proposition that the least productive land in use will yield no rent has no logical warrant. As a mere question of fact, it may quite commonly be true that some land which yields no rent is in cultivation, and the same may be true sometimes of land which yields even *less* than no rent;— that is, of land whose whole produce falls short of yielding the prevailing rate of compensation for the labor and capital employed in its cultivation; but whether the least productive land in use yields rent or not, depends upon other conditions than the circumstance of its being the least productive land in use. Question argued.

Whence rent arises. The law applicable to things which, for all practical purposes, can be produced *ad libitum* by labor, that their values are to one another as the quantities of labor necessary to their production, not applicable to land, with respect to which the law of supply and demand is, therefore, the final power in the determination of values. In short, the real cause of rent is monopoly.

Rent considered in its relation to price.

Importance of a correct theory as a basis for the action of governments upon momentous questions of public policy.

AN INTERNATIONAL ALPHABET. By MARTIN LUTHER ROUSE, Toronto, Canada.

[ABSTRACT.]

IN order to provide a systematic and easy table of reference in dictionaries, especially bilingual ones, and a code of sounds to be used by nations which for the first time adopt European letters, the essayist has devised the following international alphabet. (See chart).

The diphthongs are written simply by the vowels that compose them. Thus: *cow*, *boy*, *pare*, *parry*, *nice* and *deux* (Fr.) are spelt

kau, boi, pēǝer, pĕǝeri, nais, deeų.

But where two vowels coming together do not coalesce into a diphthong, each may receive its own mark of quantity. Thus *caïque* and *niais* (*Fr.*), *baule* and *assai* (It.), *gehen* and *thuest* (Ger.), *payer* and *devious* (E.), would stand *kāīk*, *nīĕ*, *bāūle*, *ăsāī*, *gēæn*, *tūĕst*, *pēæ*, *dīvīæs*.

In any language, however, wherein the long vowels predominate, the short alone need receive the diacritical mark; and *vice versa*.

SILK CULTURE IN THE UNITED STATES. By HARRIET A. LUCAS, Philadelphia, Pa.

THE SOCIAL WASH OF A GREAT CITY. By L. L. SEAMAN, M.D., New York, N. Y.

HOW CAN SPELLING REFORM BECOME A SUCCESS? By JNO. MÜLLER, Ann Arbor, Mich.

STATISTICS RELATING TO THE DAIRY INDUSTRY. By PETER COLLIER, Washington, D. C.

RECENT RESULTS IN THE SORGHUM SUGAR INDUSTRY. By PETER COLLIER, Washington, D. C.

INTERNATIONAL ALPHABET.

CONSONANTS.

	FLAT. Unaspirated.	FLAT. Aspirated.	SHARP. Unaspirated.	SHARP. Aspirated.	NASAL.
MUTES.					
Labials.	B,b ℬ,𝒷 Tri*b*e	V,v 𝒱,𝓋 Ri*v*e	P,p 𝒫,𝓅 Ri*p*e	F,f ℱ,𝒻 Ri*f*e	M,m ℳ,𝓂 Ri*m*e
Dentals.	D,d 𝒟,𝒹 Blee*d*	Ɖ,θ ϑ,ϑ Wrea*th*e	T,t 𝒯,𝓉 Blea*t*	Ʋ,ŧ 𝒲,𝓉 Wrea*th*	N,n 𝒩,𝓃 Glea*n*
Back-Palatals.	G,g 𝒢,𝑔 Lo*g*	Q,q 𝒬,𝓆 Lo*ch* (Sc or Ger)	K,k 𝒦,𝓀 Si*ck*	X,x 𝒳,𝓍 Si*ch* (Ger)	Ŋ,ŋ 𝒩,ŋ Si*ng*
Pharyngeal.	H,h ℋ,𝒽 *H*en				
SPIRANTS.					
Liquids.	R,r ℛ,𝓇 *R*ue	R,r ℛ,𝓇 *R*ue Ca*r*te	L,l ℒ,𝓁 *L*ay Mi*l*k	Ł,ł ℒ,𝓁 *L*ait (Fr) Mi*l*k (Ir)	
Sibilants.	Z,z 𝒵,𝓏 *Z*inc Da*z*e	Ʒ,ʒ 𝒵,𝓏 *G*éant (Fr) A*z*ure	S,s 𝒮,𝓈 *S*ink Da*c*e	Σ,ʃ 𝒮,𝓈 *Sh*ine Da*sh*	

VOWELS.

LONG.	Ū,ū 𝒰,ū B*oo*m	Ō,ō 𝒪,ō M*o*te	Ꝋ̄,ꝋ̄ 𝒬,ā D*aw*n	Ā,ā 𝒜,ā P*a*th	Ǣ,ǣ ℬ,ǣ B*u*rn	Ē,ē ℰ,ē *A*ge	Ū,ū 𝒴,ȳ S*u* (Fr)	Ī,ī ℐ,ī K*ee*n
SHORT.	Ŭ,ŭ 𝒰,ŭ B*u*sh	Ŏ,ŏ 𝒪,ŏ M*o*rass	Ꝋ̆,ꝋ̆ 𝒬,ă D*o*n	Ă,ă 𝒜,ă P*a*tte (Fr)	Ǣ̆,ǣ̆ ℬ,ǣ̆ B*u*n	Ĕ,ĕ ℰ,ĕ *E*dge	Ŭ,ŭ 𝒴,y̆ S*u*t (Fr)	Ĭ,ĭ ℐ,ĭ K*i*n

EXECUTIVE PROCEEDINGS.

REPORT OF THE GENERAL SECRETARY.

GENERAL SESSIONS OF THE THIRTY-FIFTH MEETING OF THE ASSOCIATION HELD IN THE HIGH SCHOOL, BUFFALO, AUGUST 18 TO 24, 1886.

WEDNESDAY MORNING, AUGUST 18.

PRESIDENT NEWTON took the chair at 10 A. M. and introduced the Rt. Rev. Bishop COXE of the Diocese of Western New York who opened the proceedings with a prayer which he prefaced by the following remarks:

"To preface my brief 'Bidding of Prayer,' let me say a word concerning the form I intend to use. I borrow the language of an eminent American scientist[1] who says: 'The intellectual atmosphere of Alexandria for two centuries before and three centuries after the time of Christ was more modern than anything that followed down to the days of Bacon and Descartes.' I propose to offer a prayer compiled from the writings of an Alexandrian Jew of the period before Christ thus indicated, as in close relations with modern thought. The use of a prayer 2,000 years old to open a meeting of modern scientists will thus in itself proclaim the continuity of science. Let us address that God in whom another[2] tells us there is 'a recognition and a reconciliation of the philosophical schools that divided the ancient world;' while, again, it is asserted by John Fiske[3] that in this Christian theism 'the confines of modern thought are closely approached.' With such a preface to harmonize and elevate our conceptions: let us pray:

Give us, O God, the spirit of wisdom, which they that use become the friends of God, and are commended for the gifts that come from learning. In Thy hand we are, both we and our words; all wisdom and also a knowledge of work. Thou hast given us certain knowledge of things that are; namely, to know how the world was made and the operation of the elements; the beginning, ending and midst of the times; the alterations of the turning of the sun and the change of the seasons; the circuits of years and the positions of stars; the natures of living creatures; the furies of wild beasts, the violence of winds, the reasonings of men; the diversities of plants and the virtues of roots; and all such things as are either secret or manifest. By Thy wisdom all things are done, and all things made new; for wisdom is privy to the mysteries of

[1] John Fiske, Idea of God, p. 73. [2] Quoted by Fiske, *ib.*, p. 84. [3] *Ibid*, p. 86.

divine knowledge and a lover of God's work. If a man desireth much experience, thy wisdom knoweth things of old and rightly conjectureth what is to come, knowing the subtleties of languages and expounding myths; foreseeing signs and wonders and the issues of seasons and of times. For Thou, O Lord, didst create man to be immortal and madest him to be an image of thine own eternity; but the thoughts of mortal man are miserable and our devices are but uncertain; for the corruptible body presseth down the soul and the earthly tabernacle weigheth down the mind that museth upon many things. And hardly do we guess aright at things that are upon earth, and with labor do we find the things that are before us; but the things that are in Heaven who hath searched out? Oh, send Wisdom forth out of Thy holy heavens and from the throne of Thy glory, that being present she may labor with us, that we may know what is pleasing unto Thee, and be led soberly in our doings and preserved by thy power *from all mistake*. And so may the ways of men upon earth be reformed that we may be saved through wisdom. For the whole world before Thee is as a little grain of the balance, yea, as a drop of morning dew that falleth upon the earth; but Thou hast mercy upon all and lovest the things that are and abhorrest nothing which Thou hast made. Thou sparest all, for they are Thine O Lord, Thou lover of souls, and Thine uncreated Wisdom hath taught us to say,[1] 'Our Father,'" etc.

On pronouncing the Lord's prayer a quite general response was heard over the room.

The RETIRING PRESIDENT in a few graceful and appropriate words of introduction resigned the chair to his successor Professor EDWARD S. MORSE, who on entering upon his duties spoke briefly in allusion to the one idea which animated the members of the association before him. They were not, he said, usually rich in worldly goods, and were sometimes even reproached for their failure to accumulate wealth, a failure due to their unselfish absorption in scientific pursuits. As a body they had only a slight and simple organization, but they had come here for work, and were prepared to do good work in their various departments of science.

The PRESIDENT then introduced Hon. PHILIP BECKER, Mayor of Buffalo, who said:

"Mr. President and Members of the American Association for the Advancement of Science.

I have the honor to extend to you a most hearty welcome to the city of Buffalo. Ten years ago I had the pleasure of receiving and welcoming your Association in a similar manner, and I can assure you that your visits are remembered by our citizens with pride and pleasure. It is not often that our city is honored by the presence of such a distinguished body with such direct object of doing good to all.

[1] It is proper to say that this prayer (compiled from the Book of Wisdom, Chapter VI, etc.) was used by the bishop in the meeting of the Association at Baltimore in 1858.

You are in the hands of friends, and our Local Committee will provide for your comfort and pleasure, and I trust that they will so arrange that your leisure hours may be devoted to visiting places of interest in and about our fair city. May your deliberations and studies be of mutual benefit, as they must be of public interest.

I will not detain you from your work, and so again I offer you a cordial welcome as well as the freedom and hospitality of the Queen City of the Lakes."

The Hon. SHERMAN S. ROGERS, Chairman of the Local Committee, gave the address of welcome to the Association on behalf of the citizens in the following words:

"President Morse, and Ladies and Gentlemen of the Association:—I am sure the cordial greeting that His Honor the Mayor has extended to you is not merely the formal salutation of the city. It expresses the lively pleasure and the hearty welcome of our citizens. Your association is indeed not only our honored guest, but we feel that we have some right to claim it as an old friend. Twenty years ago when you first accepted our hospitality you were welcome; ten years later you were doubly welcome; and now that you have done us the honor to visit us once more we must disavow anything less than geometrical progression in the pleasure with which we meet you. When you come again and again in future years, as we trust you may, we will call upon Prof. Pohlman, or some other learned man, to express our gratification by algebraic formula.

I read in *Science* only a few days ago that Buffalo, at the present meeting of your association, would be the first city to enjoy the honor of entertaining the association a third time. Well, there seems to be something in this worthy of municipal pride. There is, indeed, a growing impression that Buffalo is destined to become a great city. That is to say, that in the not remote future it is to have a great population and an enormous development of the material strength of our civilization, but we cannot deny that at the present New York and Philadelphia and Boston and St. Louis and Cincinnati have thicker directories than even our last plethoric volume; that they are richer and stronger and bigger and, perhaps, better than Buffalo. That is all very well. But Buffalo stands complacently this morning on this fact, definitely ascertained and incontrovertible: no other city has entertained this association a third time.

If I were asked to give a reason for Buffalo's pride in this I might not untruthfully say I think that eager as this active and enterprising city is in the material pursuits of life it is gradually waking up to the conviction that man does not and cannot live by bread alone. If you have time to look about you in these busy days of conference, I think you will see the signs of this. Just yonder beyond the Soldiers' Monument you will see a new building fast approaching completion which the Buffalo Library with the assistance of many citizens, rich and poor alike contributing, is erecting, in which to house its valuable collection of books, and where the fine Arts Academy, the Historical Society, and last but not least our local Society of Natural Sciences, may find a suitable home.

A little farther up the street you will see the fine building of the German Young Men's Association, the great Music Hall, also in process of construction. These and other conspicuous examples attest the fact that every great building in Buffalo is not either an elevator or a brewery.

And so, Mr. President, I think I may fairly claim (and this will be my last bit of boasting) that there is an increasing number in Buffalo of those who are glad now and then to see somebody, and to know somebody and to emulate somebody who, like the great Agassiz, 'has not time to make money.' By your presence among us at this time we hope this spirit will be fostered and given great enlargement. Then perhaps the friendly editor of *Science* may not have any excuse for asking whether in coming to Buffalo you are not doing missionary work *in partibus infidelium*. And so again, Mr. President and ladies and gentlemen, reëchoing the Mayor's words, let me say on behalf of the citizens' committee, you are welcome, —heartily welcome."

President Morse, for the Association, replied as follows:

"On behalf of the Association I have the honor to return most grateful thanks for your hearty and hospitable welcome. Frankness compels me to admit that it was with no little hesitation and timidity that we accepted for the third time the invitation of your citizens to make this the place of our meeting. We were royally entertained here twenty years ago, and I may say that the sweet memories of that delightful occasion urged us the more promptly to accept a second invitation which brought us to your city ten years ago. Even then our family had grown so large that a community less hospitably inclined than yours, might well have hesitated before burdening itself with the entertainment of so large a number for so long a time. And now we are here again in still greater numbers, and though your city is filled to overflowing by large conventions, the latch-strings are not pulled in. On the contrary, they have guided us by various routes to your very doors, and here on the threshold you bid us the same cordial welcome as of yore, for which, again, on behalf of all the members here assembled, I return most heartfelt thanks."

In the course of some general remarks the president further said that it was a matter of note that two members who were with the association here ten years ago — Professor Rogers and Judge Clinton — were not with us now. Both had died in the harness. Judge Clinton while pursuing his favorite study of botany was found dead by the roadside, and Professor Rogers fell dead on the speakers' platform. He proceeded to remind the association of the existence of cranks, even among its members. These people were so persistent in thrusting papers on the meetings, that the utmost vigilance was necessary to keep them out. Of course, such members were always certain that all the other members were crazy, but they must be allowed to think themselves the only sane members, and their effusions must be weeded out. The president defended the word "crank." It was not slang, but had a proper usage in the older literature. Alluding to the rapid growth of Buffalo, he said that he judged it to be no mushroom growth, but one of permanence. Mentioning the significant fact

that fifty years ago the city contained sixty-nine attorneys and but eighteen surveyors, he wondered if that proportion remained, adding that both lawyers and clergymen were usually very numerous, even in far western towns. Turning to the primary cause of Buffalo's growth, the Erie Canal, President Morse read the following extract from the Directory of 1836, which very much amused everybody, while it showed as well as might be the astonishing material growth of the past fifty years:—

"By the construction of the Erie Canal from Hudson River to Lake Erie a safe, easy, expeditious, and cheap mode of travelling and transmitting heavy merchandise was provided, which of necessity has become and must forever remain the principal thoroughfare. Goods can be shipped in New York and safely landed in Chicago in twelve days, with only two reshipments at cheap rates."

The GENERAL SECRETARY then announced that pursuant to the amendment to the constitution adopted last year, vesting the election of new members in the STANDING COMMITTEE, 86 new members had been elected since the close of the last meeting in Ann Arbor whose names would be found printed on the programme for the day and who could obtain their certificates and badges by applying at the office of the PERMANENT SECRETARY; that 160 titles of papers had been received, several of which were not accompanied by the required abstracts and so were not referred to the sections under the rule; and that Mr. EDWARD ATKINSON of Boston would address the Association on Friday evening at Liedertafel Hall, in place of Mr. ASHBURNER who was prevented by illness.

The PERMANENT SECRETARY then called for action on the proposed amendments to the Constitution, and the following were adopted.

ARTICLE 4 of the Constitution to be amended so as to read as follows:

ART. 4. Fellows shall be elected by the Standing Committee from such of the members as are professionally engaged in science, or have by their labors aided in advancing science. The election of Fellows shall be by ballot and a majority vote of the members of the Standing Committee at a designated meeting of the Committee.

ART. 18 was amended by omitting the word "nominate" in the twenty-fifth line and the following clauses were added:

The Standing Committee shall receive all reports of Special Committees and decide upon them, and only such shall be read in General Session as the Standing Committee shall direct.

The Standing Committee shall appoint at each meeting the following sub-committees who shall act, subject to appeal to the whole committee, until their successors are appointed at the following meeting: 1, on Papers and Reports; 2, on Members; 3, on Fellows.

ART. 21 was changed so as to read as follows:

A General Session shall be held at 10 o'clock A. M. on the first day of the meeting, and at such other times as the Standing Committee shall direct.

The second sentence of ART. 31 was changed so as to read as follows:

Authors must prepare their papers or abstracts ready for the press and these must be in the hands of the Secretaries of the Sections before the

final adjournment of the meeting, otherwise only the titles will appear in the printed volume.

The following general change is proposed for action at the next meeting:

That the word "Council" be substituted for "Standing Committee" throughout the Constitution.

Dr. C. S. MINOT gave notice that at the next meeting of the Association he would ask action on an amendment to the Constitution making the General Secretary and Assistant General Secretary eligible to reëlection.

The PERMANENT SECRETARY called attention to the following list of deceased members:

Notices of the decease of the following-named members of the Association have been received since the Ann Arbor meeting:

Thomas Bassnett, Jacksonville, Fla. (8). A life member. Died Feb. 16, 1886, aged 79.

Henry C. Beckwith, Coleman's Springs, N. Y. (29). Died July 12, 1885.

M. P. Costin, Fordham, N. Y. (30). Died June 8, 1884.

J. H. Devereaux, Cleveland, Ohio (18). A life member. Died March 17, 1886.

George B. Dixwell, Boston, Mass. (29). Died April, 1885.

Spencer Hedden Freeman, Cleveland, Ohio (29). Born Oct. 8, 1855. Died Feb. 2, 1886.

Myron H. Harding, Lawrenceburg, Ind. (30). Died Sept., 1885.

W. C. Hicks, New York, N. Y. (34). Died 1885.

Mrs. S. W. Holman, Boston, Mass. (29). Died May 5, 1885.

A. E. Hoppock, Hastings-on-Hudson, N. Y. (29).

Franklin B. Hough, Lowville, N. Y. (4). Born in 1822. Died June 11, 1885.

Washington Caruthers Kerr, Raleigh, N. C. (10). Died Aug. 9, 1885, aged 56.

Henry P. Kidder, Boston, Mass. (29). Born Jan. 8, 1823. Died Jan. 28, 1886.

Edward Lawrence, Charlestown, Mass. (18). Born June, 1810. Died Oct. 17, 1885.

Emile F. Loiseau, Brussels, Belgium (33). Died April 30, 1886.

J. R. Lowrie, Warriorsmark, Pa. (29). Died Dec. 10, 1885.

James Macfarlane, Towanda, Pa. (29). Died 1885.

William Muir, Montreal, Canada (31). Died July, 1885.

William Ripley Nichols, Boston, Mass. (18). Vice-President at the last meeting. Died July 14, 1886, aged 39.

W. G. Platt, Philadelphia, Pa. (22). Died Nov., 1885.

Mrs. Erminnie A. Smith, Jersey City, N. J. (25). Secretary of Section H at the last meeting. Died June 9, 1886, aged 48.

George Sutton, Aurora, Ind. (20). Died June 13, 1886.

Charles O. Thompson, Terre Haute, Ind. (29). Died 1885.

Henry R. Thomson, Crawfordsville, Ind. (30). Died 1884.

George Washington Warren, Boston, Mass. (18). Died 1884.

John Welsh, Philadelphia, Pa. (33). Died May, 1886.

Edmund B. Whitman, Cambridge, Mass. (29). Died Sept. 2, 1883.
Graham Wilder, Louisville, Ky. (30). Born July 1, 1843. Died Jan. 16, 1885.
Frank Williams, Buffalo, N. Y. (25). Died Aug. 13, 1884.
Elizur Wright, Boston, Mass. (31). A life member. Born Feb. 12, 1804. Died Nov. 20, 1885.

[During the meeting, notice was received of the death on Aug. 18 (the opening day of the meeting) of Eli W. Blake of New Haven, an original member of the Association, in his 91st year.]

The announcements of the LOCAL COMMITTEE were made and referred to as being printed on the daily programme.

The General Session then adjourned.

WEDNESDAY EVENING, AUG. 18.

PRESIDENT MORSE in the chair, who introduced with appropriate remarks the retiring President, Professor NEWTON of Yale, who then proceeded to deliver the annual address on "Meteors, Meteorites and Shooting Stars" which appears in another part of this volume (see p. 1).

At the close of the address, Professor SIMON NEWCOMB moved a vote of thanks to the distinguished speaker for his address on a subject which he had done more than any other man to investigate. This motion, after eulogistic remarks by other members of the Association, was unanimously adopted.

TUESDAY MORNING, AUG. 24.

Pursuant to the order of the STANDING COMMITTEE, based on the recent amendment to the constitution, no general morning sessions were held until the last day of the session.

PRESIDENT E. S. MORSE being in the chair, the GENERAL SECRETARY announced that up to the present time one hundred and forty-eight new members had been elected and two hundred and fifty-two papers had been received, of which two hundred and seventeen had been read in the several sections, and thirty-five had not been passed by the committee, either as not appropriate to the association or from the lack of proper abstracts. He also stated that the following fifty-seven members had been elected *fellows* by the STANDING COMMITTEE in accordance with a recent amendment to the constitution.

LIST OF FELLOWS ELECTED AUGUST 23, 1886.

1. Eugene M. Aaron, P. O. Box 916, Philadelphia, Pa. (33). **F**
2. Col. James W. Abert, Newport, Ky (31). **D**
3. Wm. S. Auchincloss, 209 Church street, Philadelphia, Pa. (29). **D A**
4. Howard Ayres, Museum Comp. Zoology, Cambridge, Mass. (34). **F**
5. Frank Baker, M.D., 326 C street, N. W., Washington, D. C. (31). **F H**
6. Rev. Wm. M. Beauchamp, Baldwinsville, N. Y. (34). **H**
7. M. S. Bebb, Rockford, Ill. (34). **F**

8. Wooster W. Beman, 11 South Fifth St., Ann Arbor, Mich. (34) **A**
9. Chas. G. Boerner, Vevay, Ind. (29). **A B E**
10. John C. Branner, Indiana University, Bloomington, Ind. (34). **E F**
11. Wm. R. Brooks, Phelps, N. Y. (35). **A**
12. Gustav Brühl, cor. John and Hopkins Sts., Cincinnati, O. (28). **H**
13. Charles F. Brush, Brush Electric Light Co., Cleveland, O. (35). **B**
14. Dr. J. H. Chapin, Meriden, Conn. (33). **E H**
15. John W. Cloud, Altoona, Pa. (28) **A B D**
16. Elmer L. Corthell, 34 Nassau St., Room 709, New York, N. Y. (34). **D**
17. Fred. P. Dewey, Ph.B., Smithsonian Institution, Washington, D. C. (30). **C E**
18. Walter A. Dun, M.D., 63 E. Fourth St., Cincinnati, O. (31). **H**
19. Theodore N. Ely, Supt. of Motive Power, Penn. R. R., Altoona, Pa. (29).
20. Charles E. Emery, 22 Cortlandt St., New York, N. Y. (34). **D B A**
21. Henry Farquhar, Coast Survey Office, Washington, D. C. (33). **A**
22. Joseph G. Fox, Lafayette College, Easton, Pa. (31). **A B**
23. Wm. Frear, State College, Centre County, Pa. (33). **C**
24. Albert C. Hale, Ph.D., Box 65, Brooklyn, N. Y. (29). **C B**
25. Uriah R. Harris, Lieutenant U. S. N., Navy Yard, Mare Island, Cal. (34). **A**
26. A. C. Hobbs, Bridgeport, Conn. (28). **D**
27. John B. Johnson, Washington University, St. Louis, Mo. (33). **D**
28. Otis C. Johnson, Ann Arbor, Mich. (34). **C**
29. J. Sterling Kingsley, Malden, Mass. (33). **F**
30. Ethan Pendleton Larkin, Ph.D., Alfred University, Alfred Centre, N. Y. (33). **F E**
31. A. Macfarlane, University of Texas, Austin, Texas, (34). **B A**
32. Miss Lillie J. Martin, High School, Indianapolis, Ind. (32). **F C**
33. Dr. Wm. P. Mason, Troy, N. Y. (31). **C B**
34. Geo. B. Maxwell, Wyoming, Hamilton County, Ohio (30). **H E**
35. T. Wesley Mills, Montreal, Can. (31). **F**
36. John Murdoch, Smithsonian Institution, Washington, D. C. (29). **F H**
37. Dr. Charles A. Oliver, 1507 Locust street, Philadelphia, Pa. (33). **F H B**
38. Benj. O. Pierce, Jr., Harvard College, Cambridge, Mass. (29). **A B**
39. Edward S. Philbrick, Brooklyn, Mass. (29). **D**
40. Edgar Richards, Department of Agriculture, Washington, D. C. (31). **C**
41. Isaac P. Roberts, Ithaca, N. Y. (33). **I**
42. Jeremiah Wilson Sanborn, Agric. Coll., Columbia, Mo. (31).
43. Rev. John W. Sanborn, Albion, N. Y. (33). **H**
44. J. M. Schaeberle, Ann Arbor, Mich. (34).
45. Wm. T. Sedgwick, Mass. Inst. of Technology, Boston, Mass. (33). **F**

46. Horace See, 1230 Spruce street, Philadelphia, Pa. (34). **D**
47. R. H. Soule, Frankfort, N. Y. (33). **D**
48. Volney M. Spaulding, Ann Arbor, Mich. (34). **F**
49. Wm. M. Thornton, University of Virginia, Va. (33). **D A**
50. James E. Todd, Tabor, Fremont County, Iowa (22). **E F**
51. Samuel W. Very, Lieutenant U. S. N., Warehouse Pt., Conn. (28). **A B**
52. Dr. Joseph W. Warren, 107 Boylston street, Boston, Mass. (31). **F**
53. Oliver C. Wendell, Observatory, Cambridge, Mass. (29). **A**
54. Channing Whitaker, Box 524, Lowell, Mass. (29).
55. Geo. Huntington Williams, Johns Hopkins University, Baltimore, Md. (33). **E**
56. Joseph M. Wilson, 435 Chestnut street, Philadelphia, Pa. (33). **D**
57. A. V. E. Young, Northwestern University, Evanston, Ill. (33). **C B**

The GENERAL SECRETARY reported, with the endorsement of the STANDING COMMITTEE, the nomination by the Standing Committee, approved by Section C, of Monsieur MICHEL EUGENE CHEVREUL to be an Honorary Fellow of this Association, and that the announcement of his election be sent to him by a cable despatch on his approaching hundredth birthday. This nomination was enthusiastically confirmed and the Secretary by vote cast the ballot of the Association, electing Monsieur Chevreul an Honorary Fellow.

By instruction of the STANDING COMMITTEE, the Secretary then read abstracts of the reports of the PERMANENT COMMITTEES OF THE ASSOCIATION. Committees No. 2, 3, 9, 10 and 11 which had made no reports were recommended to be discontinued, and the recommendation was adopted by the Association.

Committee 4 reported progress in impressing Congress with the importance of a uniform registry of births, deaths and marriages and expressed the hope of soon being able to accomplish its object. The committee was continued.

Committee 5 reported progress briefly in print and was continued.

Committee 6 reported its correspondence with the British Association in regard to holding a Scientific Congress in London, and that the matter is to come before the British Association at its approaching meeting. The committee was continued.

Committee 7 made a printed report of its progress with an account of several Indexes of Chemical Literature already printed and of several others projected or in progress, together with an appendix on modes of indexing. The committee was continued and Prof. J. W. Langley of Ann Arbor was added to it in place of Prof. Remsen who had resigned.

Committee 8 submitted a report and also, in print, the report of the Proceedings of the late meeting of the International Congress of Geologists at Berlin, a résumé of the results of the three meetings already held, announced a fourth meeting to be held in London in 1888, and desired authority to add the invitation of the Association to an invitation by sev-

eral learned institutions that the Congress hold its fifth meeting in the United States. The committee was continued and its request granted by a vote of the Association.

Committee 12 reported progress and asked that Dr. Frank Baker of Washington be added to the committee. The committee continued with Dr. Baker's name added.

Committee 13 reported that it had accomplished the objects for which it was created and asked to be discharged. Request granted.

Committee 14 reported progress, enclosing a petition presented to the Postmaster General and copy of a law introduced in the U. S. Congress respecting postage on Natural History specimens. It asked to be continued with the addition of S. F. Baird of Washington to its number and for authority to change of the word "Botanical" in its title to "Natural History." Committee continued with the proposed changes.

Committee 15 reported progress and was continued.

The Association passed a hearty vote of thanks to Mr. A. H. PORTER, of Niagara Falls, for his generous offer of a valuable lot facing Prospect Park as a site for a Museum, while sanctioning the action of the STANDING COMMITTEE in declining this offer as inconsistent with the objects and resources of the Association.

Prof. T. C. MENDENHALL gave notice of a proposed amendment to ART. 36 of the Constitution, by inserting after the words "income of which" the words, during the life of the member shall form a part of the general fund of the Association, but after his death. The object of the amendment being to encourage the increase of the "Research fund" without detriment to the annual income of the Association.

The GENERAL SECRETARY reported to the meeting, with the endorsement of the STANDING COMMITTEE, the following resolution which was unanimously passed by Section A on motion of Professor NEWTON:

RESOLVED, That the Association rejoices to learn that Dr. Gould is proposing to renew the publication of the Astronomical Journal, and the Association sincerely trusts, in the interests of science, that he will be able to carry out his plan successfully.

TUESDAY EVENING, AUGUST 24.

PRESIDENT MORSE in the chair.

The GENERAL SECRETARY announced from the NOMINATING COMMITTEE the following list of officers nominated for the next meeting of the Association and, in accordance with a unanimous vote of the Association, cast a single ballot for the entire list, who were thereupon declared duly elected, as follows:—

President: S. P. LANGLEY of Allegheny, Pa.

Vice Presidents: **A.** *Mathematics and Astronomy*—WM. FERREL of Washington, D. C. **B.** *Physics*—WM. A. ANTHONY of Ithaca, N. Y. **C.** *Chemistry*—ALBERT B. PRESCOTT of Ann Arbor, Mich. **D.** *Mechanical Science*

and Engineering—ECKLEY B. COXE of Drifton, Pa. **E.** *Geology and Geography*—G. K. GILBERT, of Washington, D. C. **F.** *Biology*—W. G. FARLOW of Cambridge, Mass. **H.** *Anthropology*—D. G. BRINTON of Media, Pa. **I.** *Economic Science and Statistics*—HENRY E. ALVORD, of Amherst, Mass.

Permanent Secretary: F. W. PUTNAM of Cambridge, Mass.

General Secretary: W. H. PETTEE, of Ann Arbor, Mich.

Assistant General Secretary: J. C. ARTHUR, of Geneva, N. Y.

Secretaries of the Sections: **A.** *Mathematics and Astronomy*—HENRY M. PAUL of Washington, D. C. **B.** *Physics*—C. LEO MEES of Athens, Ohio. **C.** *Chemistry*—C. F. MABERY of Cleveland, Ohio. **D.** *Mechanical Science and Engineering*—GEO. M BOND of Hartford, Conn. **E.** *Geology and Geography*—T. B. COMSTOCK, of Champaign, Ill. **F.** *Biology*—J. HENRY COMSTOCK, of Ithaca, N. Y. **H.** *Anthropology*—F. W. LANGDON of Cincinnati, Ohio. **I.** *Economic Science and Statistics*—WM. R. LAZENBY of Columbus, Ohio.

Treasurer: WILLIAM LILLY of Mauch Chunk, Pa.

The GENERAL SECRETARY also announced that the NOMINATING COMMITTEE recommend that the selection of a place and time for the next meeting be left with the STANDING COMMITTEE. This recommendation was adopted.

Professor T. C. MENDENHALL on behalf of the STANDING COMMITTEE then introduced the following resolutions, the reading of which was frequently interrupted by applause.

RESOLVED, That in view of the generous welcome extended to the members of the Association at this, its thirty-fifth annual meeting, by the citizens of Buffalo, its hearty thanks are due and are hereby tendered as follows:

To the Local Committee for the careful and considerate manner in which it has looked after the material comforts of the Association during its sessions, and especially to the Secretary, Dr. Pohlman, who, with untiring industry and exhaustless energy, has struggled with the minute and often annoying details of organization and management, his mastery of which has contributed so largely to the success of the meeting.

That the Association fully indorses the action of its STANDING COMMITTEE in directing its president to furnish Dr. Pohlman an official letter of introduction to the German Society of Naturalists and Physicians, whose annual convention he will attend within a few weeks after the adjournment of this session.

To the Ladies' Reception Committee, whose thoughtful attention to the ladies registered as members has never been paralleled in the history of the Association; to Dr. Wright, Mrs. Rumsey and Mrs. Day for the delightful public receptions tendered the Association, with whom should also be included the members of the Buffalo Club for the kind offer of the freedom of their rooms, and many citizens of Buffalo whose number forbids their enumeration, who have generously extended to us the hospitality of

their homes; to those who organized and directed the three excursions given to members of the Association—to the Falconwood Club House, to Niagara and to Chautauqua—which were planned and executed with such skill that the best efforts of our chemical section have not resulted in the precipitation of a trace of dissatisfaction; to Dr. Cary, president of the Buffalo Cremation Society, for the opportunity afforded for the examination of the appliances belonging to that society; to the City Authorities for the use of the High School building, in which the meetings of the Association have been held; to the Press of Buffalo, which has furnished daily trustworthy and accurate reports of the proceedings of the various sections, and this, in spite of the unusual demands upon its energies in other directions during the time of the meeting; and to the Telegraph and Telephone Companies, which have recognized their obligations to science in offering important accommodations to its workers; and finally, to any not specially mentioned above, who have in any manner contributed to the success and pleasures of this meeting, which is not an echo, but rather a reverberation of that of ten years ago, and the character of which inspires even the oldest member of the Association with the hope that he may survive another decade.

Dr. D. G. BRINTON of Media, Pa., spoke eloquently and feelingly of the welcome which Buffalo had extended to the Association. Dr. Brinton said that the past week would ever call up in the minds of members some of the most pleasant recollections of their lives. He referred to Prof. Pohlman's services as local secretary, and said that his appointment as delegate to the German Association of Naturalists and Physicians was but a just tribute of the appreciation of the Association. He was the first representative of the Association sent to that body.

Prof. NEWCOMB of Washington spoke especially of the hospitality of the ladies of Buffalo. He was sure that when the new geography came to be written and the teacher asked his class "What is Buffalo noted for?' the chorus of children would cry out, "Buffalo is noted for the public spirit of her ladies."

Mr. BRASHEAR of Pittsburg paid a tribute to the press. Some people, said he, are down on reporters. I have never seen better reporters anywhere than there are in the city of Buffalo. He declared that some of the best papers read at the convention were by women. He believed that before long a woman would sit in the President's chair—of the Association. He then added his voice of praise for Buffalo to those preceding him. The only trouble, he said, was that the members had been treated too well; had eaten too much.

Dr. JASTROW of Philadelphia told how enterprising Buffalo was in having a crematory, and how well she knew both to welcome the coming and to *speed* the parting guest.

Prof. COPE of Philadelphia, in the course of congratulatory remarks on the good fortune of the Association in holding all its meetings under one roof—an unusual circumstance—proposed to leave a bit of advice to the city which had so kindly given its use. He thought that for the benefit of

the young ladies who attend the High School an elevator ought to be constructed.

Mr. KENT of Jersey City, in seconding the adoption of the resolutions, spoke a good word for the press, the telegraph and the telephone. Remarks were also made by Dr. CHAPIN and Rev. Mr. HOVEY, Prof. T. B. COMSTOCK, Mr. ELLIOT, Prof. LOVERING and Dr. GOULD, and the resolutions were unanimously adopted.

The PERMANENT SECRETARY, after alluding to the presence of his predecessor, Prof. JOSEPH LOVERING and to Dr. B. A. GOULD, both past presidents of the Association, and the active part they had taken in bringing the Association together again after the civil war, here in Buffalo, twenty years ago, showed by statistics the progress made by the Association. He exhibited a small pamphlet of the Proceedings of the Association twenty years ago and the large volume required at the present time, and read the following figures relating to the three Buffalo meetings:

	1866.	1876.	1886.
Registered members	79	215	445
New members elected	112	150	148
Papers read in sections	67	170	217
Addresses of Presidents and Vice Presidents	—	5	9
Total membership	637	867	1,956

Of the 445 members registered during the present meeting, the numbers from various places are as follows:

Buffalo 22, New York, exclusive of Buffalo, 90, Ohio 49, Pennsylvania 41, Massachusetts 39, District of Columbia 39, Michigan 31, Illinois 22, Connecticut 17, Canada 16, New Jersey 12, Mississippi 7, Indiana 7, Missouri 7, Wisconsin 6, Minnesota 6, Kansas 5, Kentucky 5, Maine 5, Tennessee 5, Iowa 4, Nebraska 3, Rhode Island 2, Louisiana 2, Maryland 1, Texas 1, Germany 1.

The thirty-fifth meeting of the Association then adjourned.

SAMUEL G. WILLIAMS,
General Secretary.

REPORT OF THE PERMANENT SECRETARY.

It was in Buffalo that the members of the Association rallied in 1866, after the civil war had caused a suspension of the meetings for five years, and twice since then has Buffalo welcomed the Association.

A brief résumé of these three periods in the history of the Association is given upon page 375 and need not be repeated here; but, in connection with it, the following items taken from the records to the date of this report may be considered.

First, in relation to the present volume. Owing to the necessity of reducing the expenses of the Association, the Standing Committee voted that the cost of the present volume should not exceed $2,500 and that the edition should be 2,500 copies. In order to make it possible to get the annual volumes through the press at an earlier date than heretofore, various amendments to the Constitution have been gradually brought about, and the Permanent Secretary made arrangements before the recent meeting to expedite the publication of the present volume. Several of the addresses and reports were put in type and stereotyped before the meeting and others were held in type to be incorporated when reached in the order of printing. The Committee also requested that the Sectional Committees should, as a rule, limit the publication of papers to brief abstracts or by title only. As a result, the present volume has been reduced in size and cost over several preceding volumes. It contains in addition to other matter, the addresses of the President and eight Vice Presidents, six committee reports, one hundred and seventeen abstracts of papers (or, in a few cases, the papers in full) and one hundred titles of papers.

Of the 148 members elected since the Ann Arbor meeting, 123 have paid the admission fee and assessment and their names have been incorporated in the list, one has declined, and twenty-four have not yet replied to the notices of their election. Two members elected at Ann Arbor have accepted and paid their fees during the present year and their names have been added to the roll, as have the names of six old members who paid arrearages. The name of Chevreul has been added to the list as the second honorary fellow of the Association; making in all an addition of 132 names. Thirty-one names have been transferred to the list of deceased members and one hundred and eighty have been dropped on account of arrearages, making the number taken from the roll 211, a decrease of 79 members during the year. On the last day of December, 1886, the total membership of the Association was 1886 as given in the present volume.

Of the fifty-seven members elected as fellows at Buffalo, fifty-four have accepted and their names have been transferred to the list of fellows. The total increase in the number of fellows over the Ann Arbor list is twenty-five. Of the 1886 members of the Association, 428 are in arrears for Ann Arbor and Buffalo assessments, amounting to $2,568, and 140 others owe the Buffalo assessment, or $420 = $2,988.

The cash account of the Permanent Secretary, covering the year including the Ann Arbor meeting and closing just prior to the Buffalo meeting, as given on the following pages, shows a balance due the secretary of $3,184.17, which would have been more than met had all the members paid their assessments during the last three years that this deficit has accumulated. This, however, is not to be expected in an association that so many join from a general interest in its objects and particularly because the annual meeting happens to be held in their city or vicinity, and who, having paid their eight dollars, attended the meeting and received their volume of proceedings, let their membership drop from inability to attend subsequent meetings. As the membership will naturally include many temporary members, it behooves all interested in the permanency of the Association to secure new members from the educated men and women of the country who are likely to be permanent members and the present list of members should be carefully examined for those who are entitled by their labors to be transferred to the list of fellows, which, naturally, will embrace a larger proportion of permanent members, although there are, of course, very many persons, who, while deeply interested in scientific pursuits, and taking great pleasure in the meetings of the Association, would consider themselves out of place if classed among those who were specially engaged in advancing science by their labors.

In relation to the finances, it must be remembered that recently three large volumes of the proceedings have been reprinted, in order to supply full sets, at a total cost to the Association of only $565 20, which will be refunded soon from sales of the volumes.

Also that the invested funds on August 1, 1886, stood as follows:

Life membership fund,	$3,077 64
General fund,	102 92
	$3,180 56

It may also be stated that the receipts since the date of the cash account presented to the meeting in August have been as follows:

Assessments previous to Buffalo meeting,	$ 354 00
" Buffalo meeting,	1,311 00
Admission fees,	535 00
Fellowship fees,	110 00
Associate fees,	180 00
On account of future assessments,	26 50
Publications sold,	41 92
Sundry receipts, including subscriptions towards paying indebtedness,	897 09
Life Membership commutations,	100 00
	$3,055 51

The expenses for the same period have been, including the distribution of the Ann Arbor volume, rent, salary of assistant secretary, expenses of Buffalo meeting and incidentals, . . . $998 61

To be carried to Life Membership fund, . . . 100 00

1,098 61

Leaving balance on hand, . . . $1,956 90

which will be required for the printing of the present volume, so that further contributions to the current funds will be most acceptable, and the payment of assessments due is essential for the cancelling of the only debt of the Association, the salary of the permanent secretary for the past three years.

F. W. PUTNAM,
Permanent Secretary.

SALEM, MASS., Dec. 31, 1886.

F. W. PUTNAM, PERMANENT SECRETARY,

Dr. THE AMERICAN ASSOCIATION FOR

1885–6.

To admission fees previous to Ann Arbor . .	$ 15 00	
" " Ann Arbor Meeting . . .	680 00	
" " Buffalo Meeting	120 00	
Fellowship fees	132 00	
		$947 00
Assessments previous to Ann Arbor . . .	660 00	
" Ann Arbor Meeting	3,009 00	
" Buffalo Meeting	1,293 00	
" Associates, Ann Arbor . . .	114 00	
" " Buffalo	9 00	
		5,085 00
Publications sold and binding	212 24	
Incidental receipts	3 64	
		215 88
Balance of reprint fund	432 97	
Interest one year	21 64	
Mrs. Herman's gift	10 00	
		464 61
Life-member commutations		250 00
		$6,962 49
Balance due Perm. Secretary, Aug. 6, 1886.		3,134 17
		$10,096 66

I have examined the above account and find

SALEM, MASS., AUGUST 7, 1886.

IN ACCOUNT WITH

THE ADVANCEMENT OF SCIENCE. Cr.

1885–6.

By 3000 copies Proceedings Vol. 34 (662 pages), Ann Arbor.		
Composition and extra corrections	$1,249 11	
Illustrations	34 14	
Paper and press-work	1,846 35	
Binding 2930 copies in paper covers . . .	703 20	
" 25 " " one-half morocco .	25 00	
" 75 " " cloth	37 50	
Making 25 cloth covers	5 00	
Wrapping 3000 copies in printed wrappers .	34 50	
Extra copies, addresses and Reports . . .	181 92	
		$4,066 72
Reprinting Vol. 2 (480 pages), 508 copies, and illustrations		1,029 81
Illustrations for Philadelphia Volume . . .		48 00
500 copies Constitution, List of Members Ann Arbor Meeting	115 53	
Expenses of Ann Arbor Meeting	358 14	
		473 67
Special circulars and envelopes for Sections D and H	41 00	
Addressing and mailing 3000 circulars Sec. D	55 75	
Special expenses Section C	9 25	
		106 00
Printing blanks, rec'pts, cards, circulars, etc.	127 25	
Postage and envelopes	266 17	
Express, including distribution Philad. Vol.	548 61	
Telegraph and telephone	2 97	
		945 00
Proceedings bought and binding	17 00	
Boxes for Proceedings	12 08	
		29 08
Office rent $108 00. Fuel $16.00	124 00	
Janitor	48 33	
General Office expenses	17 82	
Post Office box $8.00. Postal Guide $1.50 .	9 50	
Binding 36 vols. in the Library	23 40	
		223 05
Extra clerk hire and labor	87 55	
Salary of Assistant Secretary	500 00	
Salary of Permanent Secretary	1,250 00	
		1,837 55
Balance due Permanent Secretary 1884–5 Acct.		1,087 78
Life Membership Commutations to Investment Acct.		250 00
		$10,096 66

the same correctly cast and properly vouched.

HENRY WHEATLAND, *Auditor.*

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